The Journal of Bone and Joint Surgery

The Official Publication of
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
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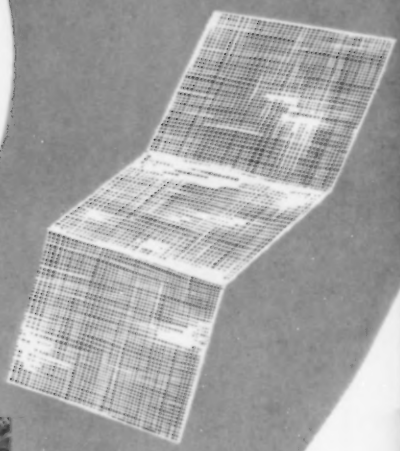

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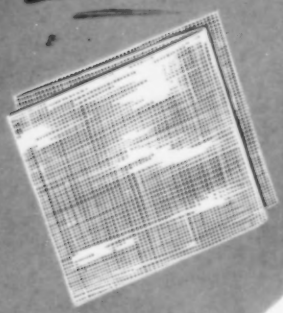

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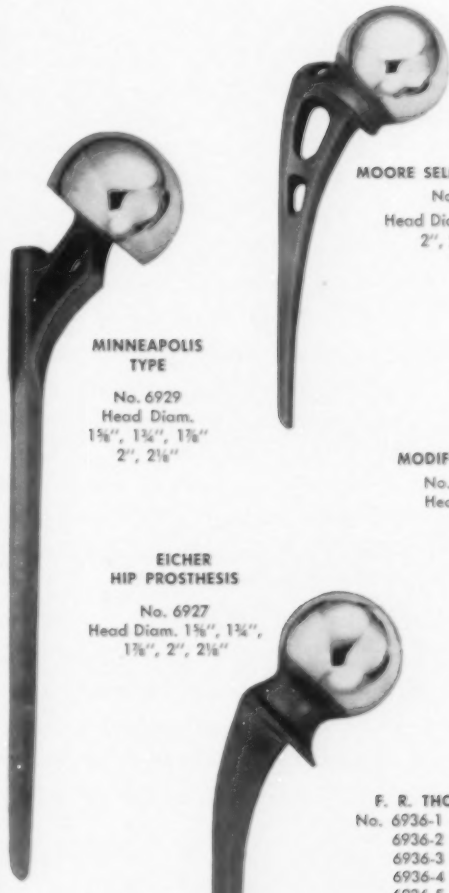

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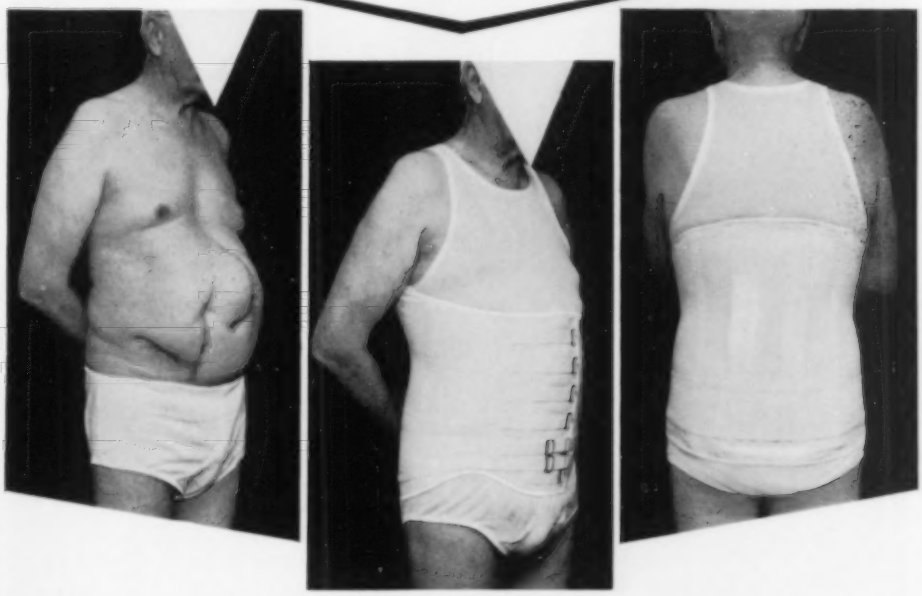

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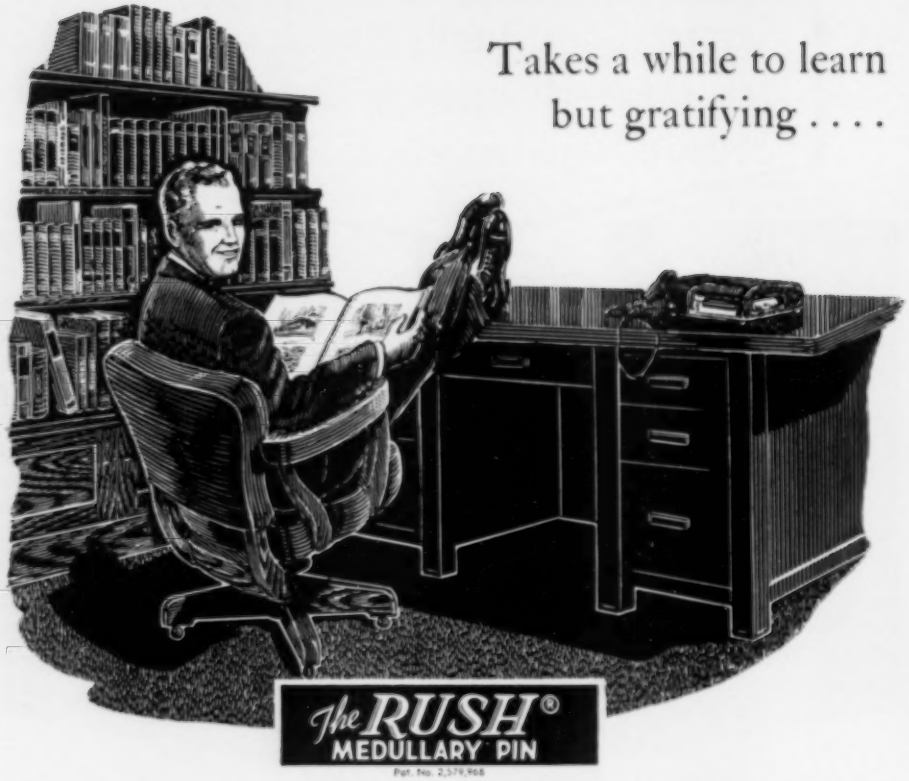

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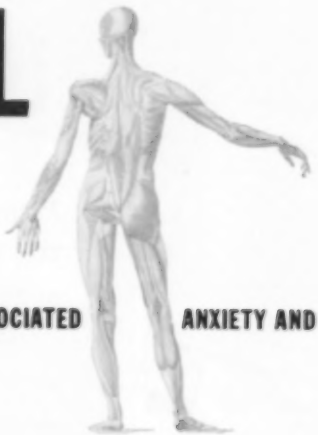

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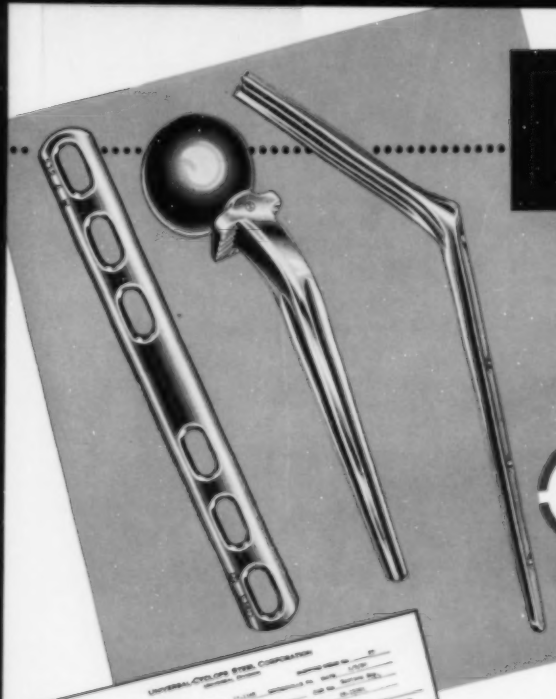

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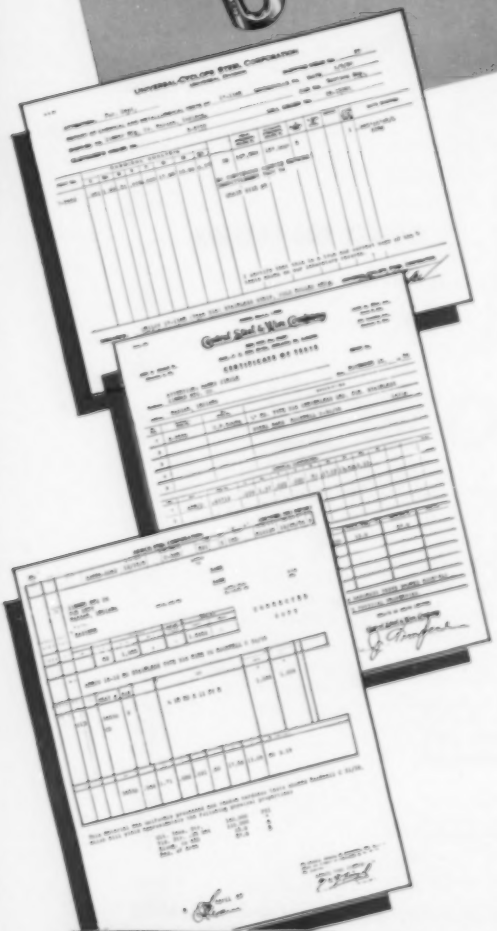


Every bar of stainless steel that goes into the manufacture of Zimmer orthopedic appliances and equipment is certified for uniformity of physical properties by the metallurgical laboratories of some of America's foremost steel mills.

Armco, Universal Cyclops and Central Steel & Wire Company all cooperate closely by furnishing certifications with each shipment. Elements alloyed in Zimmer stainless steels vary less than 1% from one production heat to another.

Such uniformity assures the orthopedic surgeon of utterly dependable implant appliances – appliances tested to resist the destructive actions of body fluids. Zimmer metals are unsurpassed.

zimmer®

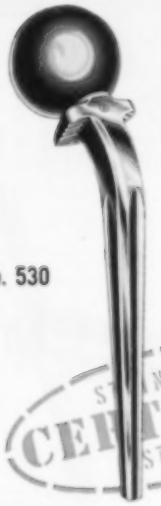
ZIMMER MANUFACTURING CO. • WARSAW, INDIANA, U.S.A

LOOK FOR THE TRADEMARK Ⓩ

appliances for orthopedic surgery

zimmer®

THE EICHER FEMORAL PROSTHETIC HEAD



No. 530

TOWNLEY PROSTHESIS

No. 815

MINNEAPOLIS PROSTHESIS

No. 535

SCHNEIDER SELF-BROACHING INTRAMEDULLARY PIN

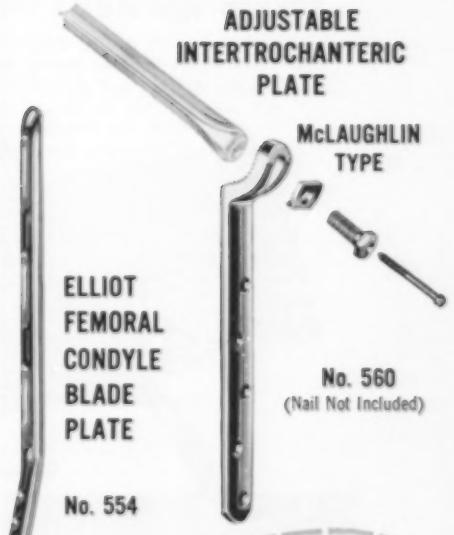
No. 825

SLOTTED PATTERN PLATES

No. 539

ADJUSTABLE INTERTROCHANTERIC PLATE

McLAUGHLIN TYPE



ELLIOT FEMORAL CONDYLE BLADE PLATE

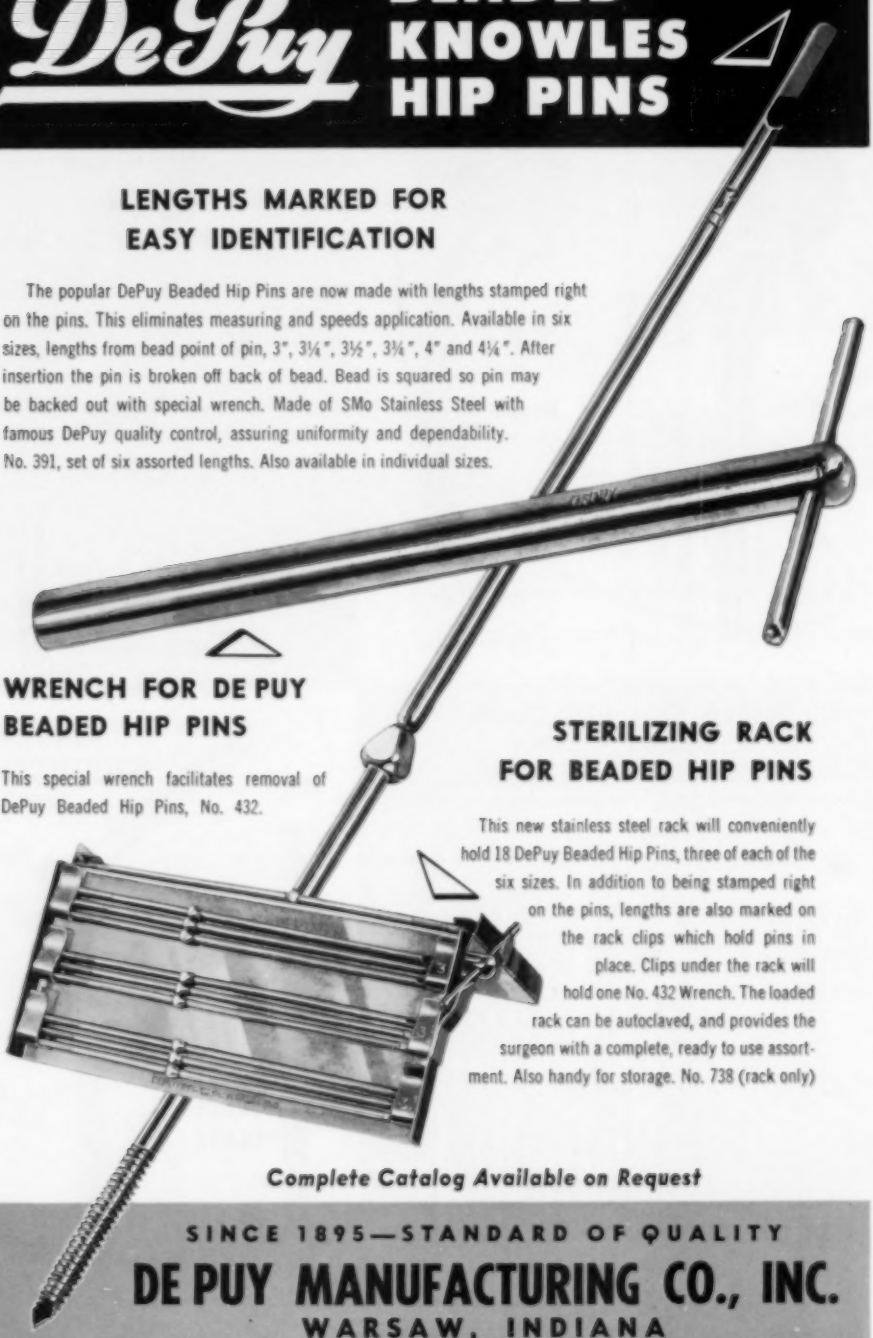
No. 554

No. 560
(Nail Not Included)

DePuy BEADED KNOWLES HIP PINS

LENGTHS MARKED FOR EASY IDENTIFICATION

The popular DePuy Beaded Hip Pins are now made with lengths stamped right on the pins. This eliminates measuring and speeds application. Available in six sizes, lengths from bead point of pin, 3", 3¼", 3½", 3¾", 4" and 4¼". After insertion the pin is broken off back of bead. Bead is squared so pin may be backed out with special wrench. Made of SMo Stainless Steel with famous DePuy quality control, assuring uniformity and dependability. No. 391, set of six assorted lengths. Also available in individual sizes.



WRENCH FOR DE PUY BEADED HIP PINS

This special wrench facilitates removal of DePuy Beaded Hip Pins, No. 432.

STERILIZING RACK FOR BEADED HIP PINS

This new stainless steel rack will conveniently hold 18 DePuy Beaded Hip Pins, three of each of the six sizes. In addition to being stamped right on the pins, lengths are also marked on the rack clips which hold pins in place. Clips under the rack will hold one No. 432 Wrench. The loaded rack can be autoclaved, and provides the surgeon with a complete, ready to use assortment. Also handy for storage. No. 738 (rack only)

Complete Catalog Available on Request

SINCE 1895—STANDARD OF QUALITY

DE PUY MANUFACTURING CO., INC.

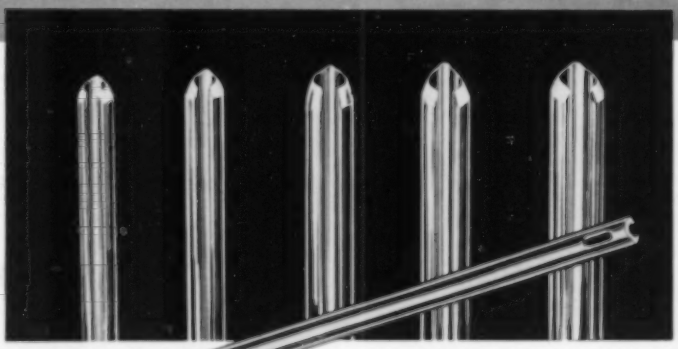
WARSAW, INDIANA

In answering advertisements, please mention *The Journal of Bone and Joint Surgery*.

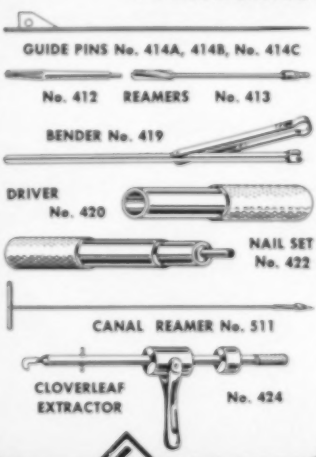
Rely on original Küntscher

CLOVERLEAF medullary NAILS

by Orthopedic



Cloverleaf Nail ACCESSORIES



. . . and get these outstanding ADVANTAGES

Built according to original Küntscher cloverleaf design for superior strength. Nails are formed by drawing (not on a punch press) so there is no possibility of fracturing metal. Made from SMo stainless steel. Nails have large slot . . . can be extracted with practically any type extractor. Greater strength results from true roundness of trefoil. Nail has rounded cusp; no sharp bends or angle points where metal can fracture.

SIZES:

- No. 401-1—Küntscher Cloverleaf Type Medullary Nail, 12 mm width, lengths 36 up to 52 cm
- No. 401—11 mm, lengths 32 up to 52 cm
- No. 402—10 mm, lengths 32 up to 52 cm
- No. 403—9 mm, lengths 32 up to 52 cm
- No. 404—8 mm, lengths 26 up to 52 cm
- No. 405—6 mm, lengths 22 up to 42 cm
  (Special lengths available upon request)

Order today from your surgical supply dealer!

Orthopedic EQUIPMENT CO.
BOURBON, INDIANA
SPLINTS • FRACTURE EQUIPMENT • SMo INTERNAL BONE APPLIANCES • BONE INSTRUMENTS

OSTIC® PLASTER BANDAGES
won't give you casts this strong

But they give you the strength any patient needs— and all these extras, too:

	OSTIC	Bandage B	Bandage C
Waterproof package (prevents presetting)	YES	NO	YES
Setting time controlled within 20 seconds	YES	NO	NO
Available in both fast and extra-fast setting	YES	YES	NO
Plaster loss less than 3%	YES	YES	YES
Nonravelling edges	YES	YES	YES
Available in colors for kids	YES	YES	NO
Colors are washable pigments (not dyes). Won't stain fabrics. No gloves needed.	YES	NO	—

GIVE KIDS MEMBERSHIPS IN THE CURITY HERO CLUB

Youngsters' spirits rise when you make 'em members of the Curity Hero Club. (And you get better co-operation.) Hero's badges and certificates of membership packed inside every box of Ostic in Colors.

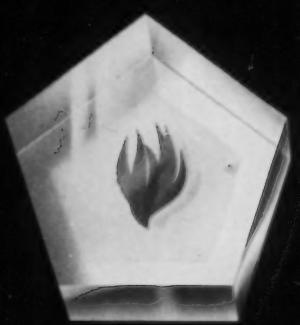
Curity®
OSTIC
PLASTER BANDAGES

Bauer & Black
DIVISION OF THE KENDALL COMPANY

announcing

a new order of magnitude in corticosteroid therapy!

The great corticosteroid era opened ten years ago with the introduction of Cortone* (Cortisone). Today, MERCK SHARP & DOHME proudly presents the crowning achievement of the first corticosteroid decade—DECADRON (dexamethasone)—a new and unique compound, which brings a new order of magnitude to corticosteroid therapy.



Decadron*

DEXAMETHASONE

to treat more patients more effectively

MSD

MERCK SHARP & DOHME
DIVISION OF MERCK & CO., INC.
PHILADELPHIA 1, PENNSYLVANIA

a new order of magnitude

in anti-inflammatory potency

DECADRON "possesses greater anti-inflammatory potency per milligram than any steroid yet produced,"[1] and is "the most potent steroid thus far synthesized."[2] Milligram for milligram, it is, on the average, 5 times more potent than 6-methylprednisolone or triamcinolone; 7 times more potent than prednisone; 28 times more potent than hydrocortisone; and 35 times more potent than cortisone.

in dosage reduction

Thanks to this unprecedented potency, DECADRON is "highly effective in suppressing the manifestations of rheumatoid arthritis when administered in remarkably small daily milligram doses."[3] In a number of cases, doses as low as 0.5-0.8 mg. proved sufficient for daily maintenance. The average maintenance dosage in rheumatoid arthritis is about 1.5 mg. daily.

in elimination and reduction of side effects

Virtual **absence of diabetogenic activity, edema, sodium or water retention, hypertension, or psychic reactions** has been noted with DECADRON.[1,2,3,4] Other "classical" reactions were less frequent and less severe. DECADRON showed no increase in ulcerogenic potential, and **digestive complaints were rare. Nor have there been any new or "peculiar" side effects,** such as muscle wasting, leg cramps, weakness, depression, anorexia, weight loss, headache, dizziness, tachycardia, or erythema. Thus DECADRON introduces **a new order of magnitude in safety,** unprecedented in corticosteroid therapy.

in therapeutic effectiveness

With DECADRON, investigators note "a decided intensification of the anti-inflammatory activity"[3] and antirheumatic potency.[4] Clinically, this was manifested by a **higher degree of improvement** in many patients previously treated with prednisteroids,[3] and by **achievement of satisfactory control in an impressive number of recalcitrant cases.**[3,4]

in therapeutic range

More patients can be treated **more effectively** with DECADRON. Its higher anti-inflammatory potency frequently brings relief to cases resistant to other steroids. Virtual freedom from diabetogenic effect in therapeutic dosage permits treatment of many diabetics without an increase in insulin requirements. Absence of hypertension and of sodium and fluid retention allows effective therapy of many patients with cardiovascular disorders. Reduction in the incidence and severity of many side effects extends the benefits of therapy to numerous patients who could not tolerate other steroids. And a healthy sense of well-being, reported by nearly all patients on DECADRON, assures greater patient cooperation.

References:
1. Boland, E. W.: California Med. 88:417 (June) 1958. 2. Bunim, J. J., et al.: Arthr. & Rheum. 1:313 (Aug.) 1958 3. Boland, E. W., and Headley, N. E.: Paper read before the Am. Rheum. Assoc., June 21, 1958, San Francisco, Calif. 4. Bunim, J. J., et al.: Paper read before the Am. Rheum. Assoc., June 21, 1958, San Francisco, Calif.

In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*

To treat more patients more effectively
in all allergic and inflammatory disorders
amenable to corticosteroid therapy

DOSAGE AND ADMINISTRATION
With proper adjustment of dosage, treatment may ordinarily be changed over to DECADRON from any other corticosteroid on the basis of the following milligram equivalence:

One 0.75 mg. tablet of Decadron* (dexamethasone) replaces:

one 4 mg. tablet of	one 5 mg. tablet of	one 20 mg. tablet of	one 25 mg. tablet of
methylprednisolone or triamcinolone	prednisolone or prednisone	hydrocortisone	cortisone

SUPPLIED:
As 0.75 mg. scored pentagon-shaped tablets; also as 0.5 mg. tablets, to provide maximal individualized flexibility of dosage adjustment.

Decadron*

DEXAMETHASONE

Detailed literature on DECADRON is available to physicians on request.

*DECADRON is a trademark of Merck & Co., Inc.

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announcing

a new order of magnitude in corticosteroid therapy!

The great corticosteroid era opened ten years ago with the introduction of Cortane® (Cortisone). Today, MERCK SHARP & DOHME proudly presents the crowning achievement of the first corticosteroid decade—DECADRON (dexamethasone)—a new and unique compound, which brings a new order of magnitude to corticosteroid therapy.

Decadron*

DEXAMETHASONE

to treat more patients more effectively

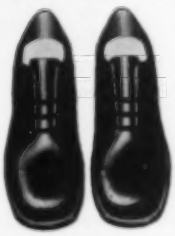
MSD MERCK SHARP & DOHME

Prescribe with confidence . . .

recommend Edwards *Pedic Shoes*

Fifty-seven years of craftsmanship go into the making of Edwards Pedic shoes, the only complete line of children's prescription shoes in America. Ideal for lateral or medial wedging, Edwards Pedics are made on tested lasts, from clinic-approved patterns. Write for the name of your nearest Edwards dealer, who is trained in prescription fitting, and for a Pedic brochure.

Pronation



COREC TRED
for mild cases
(also available in boot)

SUPER-PEDIC
for extreme cases
(also available in oxford)

Supination

PIGEON-TOE
for mild cases
(also available in oxford)

PRONA-PEDIC
for extreme cases
(also available in oxford)

Pre-Walkers

REVERSE LAST

STRAIGHT-LAST

Straight-Lasts

SURGICAL BOOT

REGULAR BOOT

THOMAS HEEL
EXTENDED
COUNTER
(Also available in oxford)

Edwards®

The Shoe for Children

PHILADELPHIA 7, PENNSYLVANIA

In answering advertisements, please mention *The Journal of Bone and Joint Surgery*.

IS THIS YOUR PATIENT?

1.

EARLY POSTMENOPAUSE

Complains of low back pain, vague aches and fatigue

Posture is poor

No x-ray evidence of bone lesions

2.

LATER POSTMENOPAUSE

Back pain is severe, spreading to hips ("girdle pain")

Patient is round shouldered, walks with a stoop

X-ray reveals compression fractures of lower vertebrae

3.

70 AND OVER

Fracture of hip after a minor fall

X-ray reveals fracture of neck of femur

X-ray reveals compression fractures of lower lumbar vertebrae

These three patients have osteoporosis. Early diagnosis and treatment with "Formatrix" is important because osteoporosis is probably the only age change that can be averted. With "Formatrix" therapy, relief from the symptoms of *low back pain, vague aches* and *fatigue* may be obtained in as little as a few weeks. "Formatrix" supplies the essential materials to stimulate increased bone formation and prevent further loss of bone substance that leads eventually to loss of height, stooped posture, and disabling fractures.

The highest incidence of osteoporosis may be found among the 14,000,000 women in the U.S.A. who are 55 years of age and over. Some investigators claim that almost all women past the menopause will show some degree of osteoporosis; furthermore, if all these women were examined carefully, 50 per cent would show x-ray evidence of decreased bone mass.

Suspicion may be the handiest diagnostic tool since presenting symptoms vary from mild to severe and incapacitating pain, and no x-ray evidence of spinal degeneration is available until about 30 per cent of the bone matrix is lost. Between these two extremes there are other signs of estrogen deficiency such as *wrinkled and thinning skin*, a *tendency to appear older than stated years;* there may also be *hypercalciuria* when postmenopausal osteoporosis is complicated by acute osteoporosis of disuse.

Osteoporosis is primarily an atrophic condition of bone matrix formation and any factor that depresses osteoblastic activity or retards the formation of protein and connective tissue such as *prolonged immobilization, cortisone therapy,* or *malnutrition* will favor development of osteoporosis in both male and female.

5678

Ayerst

AYERST LABORATORIES

New York 16, N. Y. • Montreal, Canada

NEW

In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*

"FORMATRIX" contains three most essential bone building materials necessary *for matrix* formation, estrogen, androgen and vitamin C.

The estrogen component of "Formatrix" stimulates osteoblastic activity, thus aiding calcium and phosphorus deposition; it also imparts a feeling of "well-being." The anabolic action of methyltestosterone promotes the synthesis of protein and restores a positive nitrogen balance. Together, these hormones have a greater effect on bone and protein metabolism than either alone, and side effects are minimized because of the opposing action of the two steroids on sex-linked tissues. Vitamin C plays an important role in formation of intercellular cement substance and amino acid synthesis. "Formatrix" has a large amount of vitamin C to aid in new bone matrix formation and to further help in the healing of fractures.

"FORMATRIX" – each tablet contains:

Conjugated estrogens equine ("Premarin"®)	1.25 mg.
Methyltestosterone	10.0 mg.
Ascorbic acid	400.0 mg.

Dosage: 1 tablet a day – In the female, three weeks of treatment with a rest period of one week between courses is recommended.

Supplied: Tablets, bottles of 60 and 500.

LITERATURE AVAILABLE ON REQUEST

1.

EARLY POSTMENOPAUSE
No x-ray evidence of bone lesion

2.

LATER POSTMENOPAUSE
X-ray reveals compression fracture of lower vertebrae

3.

70 AND OVER
X-ray reveals fracture of neck of femur

TO RELIEVE LOW BACK PAIN – TO PROMOTE HEALING OF FRACTURES

in osteoporosis

"FORMĀTRIX"

(Brand of Steroid – Vitamin Combination)

for matrix formation

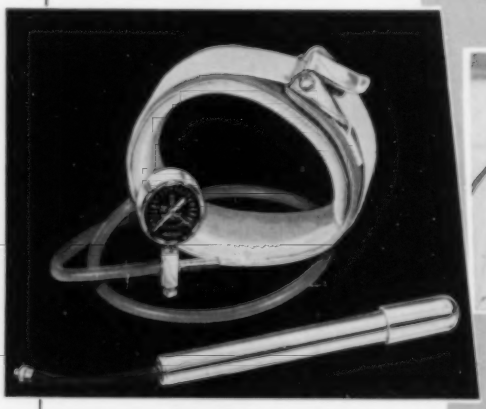
In answering advertisements, please mention *The Journal of Bone and Joint Surgery*.

Richards

NEW

PNEUMATIC

Tourniquet



Positive Retention of Pressures...

The new Richards Pneumatic Tourniquet incorporates all of the advantages of the time-tested Campbell-Boyd Tourniquet, plus improvements making for speed and ease of application with positive retention of pressure.

The new cuff, containing the inflation system, can be applied with ease in 15 seconds. An airplane belt type fastener with single wide nylon strap provides speed with positive lock. Possible roll or shifting of position of the tourniquet is prevented by improved cuff construction. The new tourniquet will lay flat against the arm or leg when inflated. Pressure is applied evenly over a large area and the exact amount of pressure is known.

The tourniquet may be deflated at any time without disturbing the operator or the sterile drapes.

An improved gage has easy-to-read white numerals with black background. Dial is calibrated in millimeters of mercury and pounds per square inch pressure, with a maximum reading of 1000 millimeters and 20 psi. Average arm and leg pressures are indicated. Only two seconds are required to remove the tourniquet.

Improved construction of the cuff which contains the Inflation System can be applied with ease in 15 seconds

No. 1310 Large—for legs. Maximum circumference 27 in.	$ 55.00
No. 1311 Medium—for adult arms. Maximum circumference 24 in.	$ 55.00
No. 1311C Small—for small legs. Maximum circumference 20 in.	$ 55.00
No. 1311CC Infant—Maximum circumference 16 in.	$ 55.00
No. 1310X Extra large—for very large thighs. Maximum circumference 35 in.	$ 60.00
Any three above sizes	$160.00

Removal of the tourniquet can be effected in 2 seconds...

RICHARDS MANUFACTURING COMPANY—756 MADISON AVENUE—MEMPHIS, TENNESSEE

Richards

BOYES-PARKER HAND OPERATING TABLE

(U. S. PATENT NO. 2,609,261)

The surgeon and his assistant will find a scientifically designed workbench, efficient and steady, in the Boyes-Parker Hand Operating Table. It eliminates tension and strain during operations. Relieves cramped positions of the hands, arms and shoulders. Space for forearms and elbows improve operative steadiness without tiring, and can thus cut down operating time by 20%.

Removeable stainless steel pan facilitates washing.

Light in weight, easy for nurse to quickly place in position. Adjustable legs allow fitting to any operating table level. Collapsible; requires minimum of storage space.

Pull-out instrument board places instruments in ready position for use.

Formica top; all stainless steel parts; conductive rubber ends on feet.

No. 454	**BOYES-PARKER HAND OPERATING TABLE (Complete with No. 454A Pan)**	**$160.00**
No. 454A	**STAINLESS PAN ONLY**	**16.00**
No. 454B	**STAINLESS STEEL PAN WITH 1/4" DRAIN PLUG**	**20.00**

RICHARDS ADJUSTABLE SURGERY STOOL

The Richards adjustable stool is designed primarily to be used with the Boyes-Parker Hand Operating Table. Constructed of durable steel tubing, chromium plated. Three legs give stability. The stool embodies the features of an ideal seat for the hand surgeon. The saddle shaped hardwood seat is firm and comfortable, with rounded edges.

The rigid stool does not swivel; there are no casters to slide. Simple and positive up and down adjustment. By sitting on a stool that does not pivot or wobble, the surgeon can maintain an efficient, tireless posture, resting the elbows on the projecting curves of the hand table.

No. 455 SURGERY STOOL.....$55.00

Richards MANUFACTURING CO., MEMPHIS, TENN.

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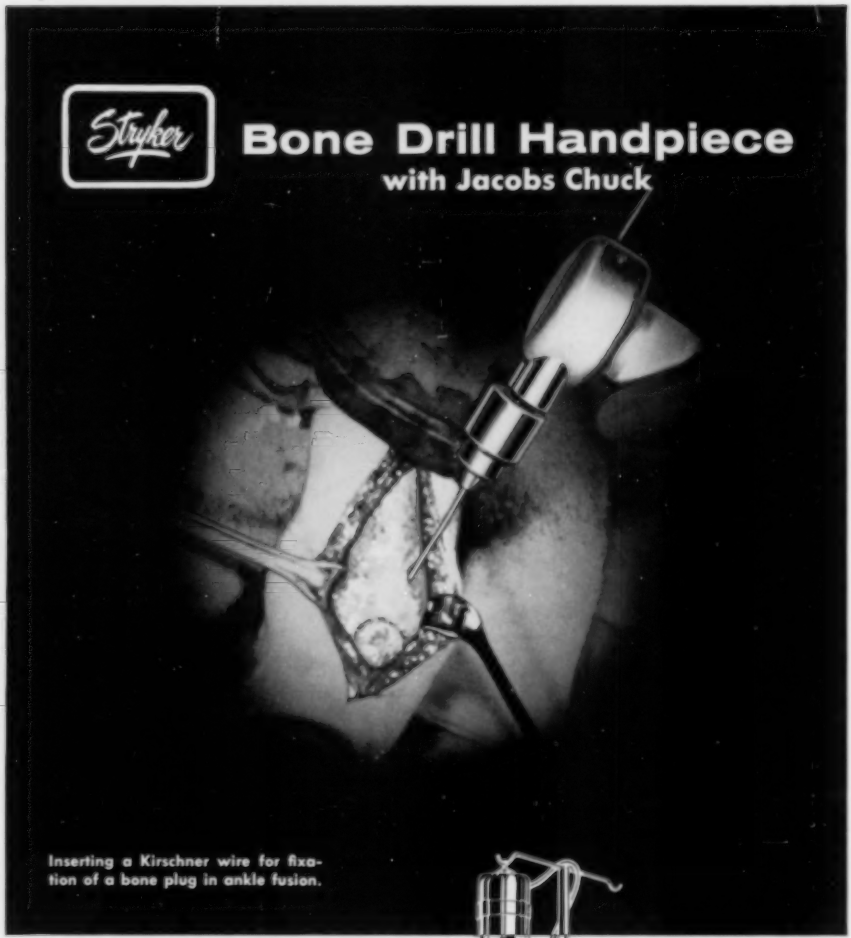
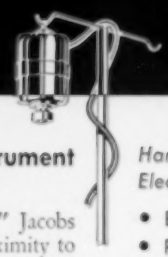
Stryker

Bone Drill Handpiece
with Jacobs Chuck



Inserting a Kirschner wire for fixation of a bone plug in ankle fusion.



. . . a Convenient, Universal Power Instrument

This balanced drill handpiece and ¼" Jacobs Chuck is cannulated to permit close proximity to the point of access with Steinmann pins and smooth or threaded Kirschner wires, guide wires or drills. Designed to save you valuable time and energy.

For additional information on the Stryker Power Unit and Jacobs Chuck, write today.

Handpieces for the Stryker Electro-Surgical Unit . . .

- Bone Saw
- Rolo-Dermatome
- Sagittal Saw
- Pencil-Grip
- Burring Handpiece
- Bone Drill Handpiece
  - Automatic Screwdriver
  - Colorguide Drill
  - Jacobs Chuck
- Colorguide Screw Case

Stryker Manufacturers of Quality Surgical and Hospital Equipment

Orthopedic Frame Company

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Distributed in Canada by: Fisher & Burpe, Ltd., Winnipeg

Exclusive Agent for Export: Schuelke & Co., 75 Cliff St., N. Y.

TWO NEW PARAFLEX* PRODUCTS

FOR RHEUMATISM AND TRAUMATIC DISORDERS

PARAFON*

THE SPECIFIC MUSCLE RELAXANT PLUS
THE PREFERRED ANALGESIC

FOR ARTHRITIS

PARAFON* with PREDNISOLONE

Effective and well tolerated on the practical dosage of only 6 tablets daily, PARAFON and PARAFON WITH PREDNISOLONE provide benefits that last for up to six hours.

PARAFON relieves pain, stiffness, and disability caused by rheumatism and traumatic disorders; PARAFON WITH PREDNISOLONE compounds this relief with anti-inflammatory action in treatment for arthritis.

supplied: PARAFON: Tablets, scored, pink, bottles of 50. Each tablet contains: PARAFLEX Chlorzoxazone† 125 mg.; and TYLENOL® Acetaminophen 300 mg.
PARAFON WITH PREDNISOLONE: Tablets, scored, buff colored, bottles of 36. Each tablet contains: PARAFLEX Chlorzoxazone 125 mg.; TYLENOL Acetaminophen 300 mg.; and prednisolone 1.0 mg.

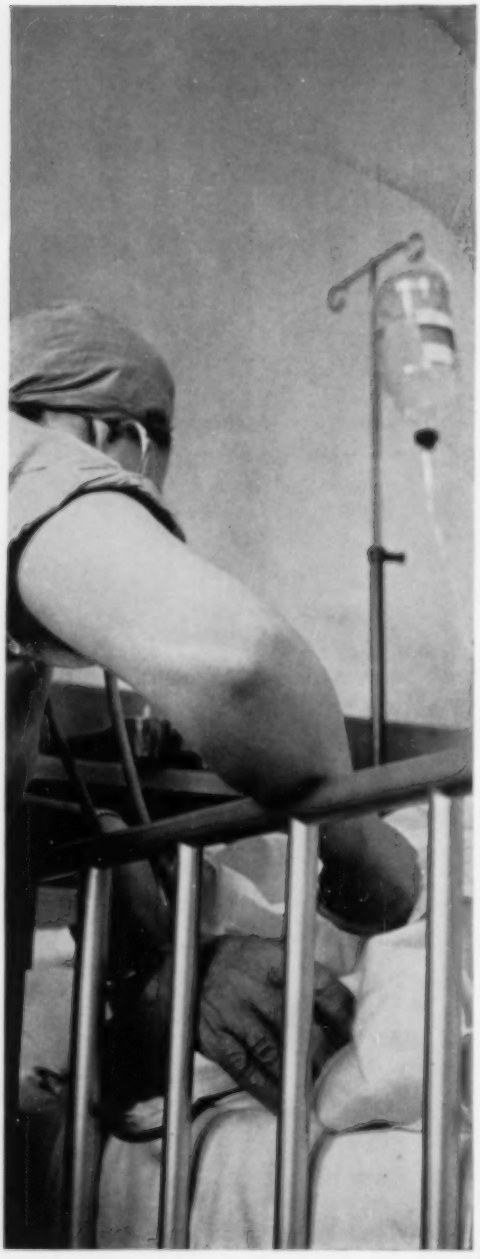
precautions: The precautions and contraindications that apply to all steroids should be kept in mind when prescribing PARAFON WITH PREDNISOLONE.

*TRADE-MARK †U.S. PATENT PENDING

McNEIL

McNeil Laboratories, Inc • Philadelphia 32, Pa.

postoperatively



Compazine* controls nausea and vomiting

- **hypotension is minimal and infrequent**
- **alerting effect, seen in many patients, facilitates early ambulation and shortens convalescence**

For immediate effect: 2 cc. Ampuls and 10 cc. Multiple dose vials, 5 mg./cc. Also available: Tablets, Spansule† sustained release capsules, Suppositories and Syrup.

Smith Kline & French Laboratories
Philadelphia

*T.M. Reg. U.S. Pat. Off. for prochlorperazine, S.K.F.

†T.M. Reg. U.S. Pat. Off. for sustained release capsules, S.K.F.

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ACTIVE CORRECTION

with lessened need
for manipulation,
plaster, tenotomy
or anesthetics

with

UNITED STATES
Manufacturing Co.

**DENIS
BROWNE
SPLINTS**

No torn sheets!
Knurled locking nuts and
rounded edges prevent
damage to bed clothes.

An important improvement in the treatment of club feet, positional deformities, tibial torsions, flat feet, congenital hip dislocations and other deformities that respond to correction by kicking.
Lightweight and strong — made of 24 ST aluminum alloy. Precision adjustment — Positive adjustment by degree angles.
Standard sizes — 6″, 8″, 12″, 14″ in stock.
16″, 18″ and 20″ bars available at slight extra cost.

SOLD ON PRESCRIPTION ONLY

You get immediate delivery anywhere when you specify

UNITED STATES *Manufacturing* COMPANY

Pre-fabricated brace parts and orthopedic equipment

NEW ADDRESS!

P.O. Box 110 • 623 South Central Avenue • Glendale 4, California
CHapman 5-6855

ESPECIALLY DESIGNED WITH THE ARTHRITIC IN MIND

Extraordinary measures, such as this especially designed toothbrush, can help your arthritic patient fulfill the demands of daily life.

Kenacort, too, is especially designed to give your arthritic patient extraordinary help. The antirheumatic, anti-inflammatory, and antiallergic activity of this new halogenated steroid provides prompt relief from pain, stiffness, and swelling, and experience shows that if it is started soon enough, it may even forestall crippling deformities.

Not only does Kenacort achieve these extraordinary benefits in arthritic disorders but it's also valuable in the treatment of allergies and asthma –

KENACORT

Squibb Triamcinolone

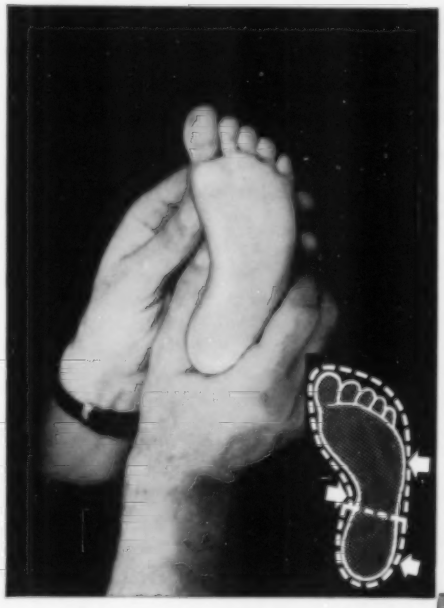
- with far less gastric disturbance
- without salt and water retention
- without unnatural psychic stimulation
- on a lower daily dosage range

SUPPLIED:
Scored tablets of 1 mg. – Bottles of 50
Scored tablets of 2 mg. – Bottles of 50
Scored tablets of 4 mg. – Bottles of 30 and 100

UTENSIL BY ADJUSTICS, INC., N. Y. C. • COURTESY, N. Y. UNIVERSITY MED. CENTER INSTITUTE OF PHYS. MED. & REHABILITATION, N. Y. C. KENACORT® IS A SQUIBB TRADEMARK

SQUIBB *Squibb Quality – The Priceless Ingredient*

the action of the TARSO SUPINATOR SHOE

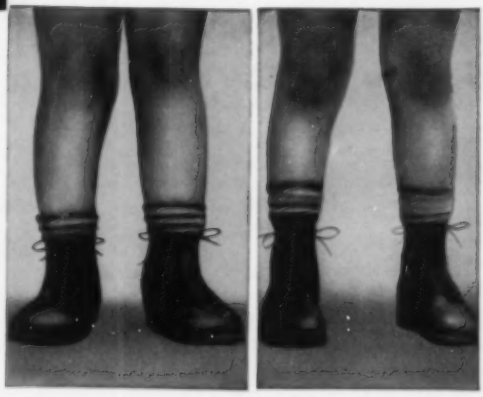


. . . swings the hind-foot inward, which induces adduction of the fore-foot, elevates the longitudinal arch, and levels the ankle joint.

When the hind-foot is held in a position of inward rotation, the talo-scaphoid and cuneiform-scaphoid joints will remain locked under weight bearing. The arch will not collapse and the ankle will not roll inward.

Correction is accomplished by the specially shaped last. Medially wedged and extended heels promote better weight distribution. Medially extended counters are used for utmost control.

See us in Chicago — January 24-29
26th Annual Meeting
American Academy of Orthopaedic Surgeons
BOOTH 78



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Tarso Shoes are ready-made and are available on prescription from dealers in most cities. Write for catalog and name of nearest dealer.

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FOR FLAT FEET

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ORIGINATORS OF TARSO PRONATOR® AND TARSO MEDIUS® SHOES

Tarso shoes have been in use for over twenty-five years.

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Because Simmons BACK CARE with Built-in Bedboard is an entirely new concept in the orthopedic-type mattress... designed especially for patients with chronic backache.

Here's why BACK CARE® can be an important adjunct to the management of backache and other disorders requiring a firm, comfortable sleeping surface . . .

1. This upper layer of 312 coils adjusts to the contours of the body for sleeping comfort.

2. This built-in *plywood* bedboard keeps the spine properly aligned . . . and exerts corrective action *close up to the back* where support is needed.

3. This lower layer of springs acts as a "floating" mechanism for the bedboard, equalizes weight over all coils and prevents "sag."

BACK CARE
WITH BUILT-IN BEDBOARD
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in the rheumatoid arthritic's shoes,
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wouldn't you want a steroid
with a proved record
of safety and success?

METICORTEN®

prednisone

you can count on rapid relief from pain, swelling and stiffness followed by functional improvement and maintained on an uncomplicated, low-dosage regimen **with minimal chance of side effects†** **and without unexplained weight loss, anorexia, muscle cramps** as reported with certain other corticoids†

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METICORTEN, 1, 2.5 and 5 mg. white tablets.

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Certified Prosthetists from the various HANGER offices have attended special courses on Upper- and Lower-Extremity Prosthetics ensuring that HANGER Clients receive the best Prosthetic Service possible.

These courses utilize many of the most recent findings of engineering and prosthetics research, and are designed as advanced training for men already actively engaged in rehabilitating amputees. The courses are approved by the American Board for Certification and given at the University of California in Los Angeles, and at the College of Engineering, New York University, in cooperation with the Prosthetic Research Board of the National Academy of Sciences.

The use of the Adjustable Leg and the new "quadrilateral socket" were features of a series of intensive courses. The curriculum was based upon the Clinical Approach to Prosthesis, centered around the Clinical Team (illustrated). This team is usually composed of a physician, a prosthetist and a therapist. It is concerned with the integrated handling of each amputee case, including prescription, fitting and check-out of the prosthesis and gait analysis and training of the wearer.

This advanced training enables HANGER Prosthetists to work closely with surgeons and physicians. Doctors interested in Prosthetics can be assured that HANGER Prosthetists are fully acquainted with the latest prosthetic methods. Be sure to call on HANGER whenever you feel we may be of service.

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The LaBerne Shoulder Rotator offers Progressive and Resistive Exercises in a complete range, for Internal and External Rotation, Unilateral and Bilateral Extensor, Scapula Rotation, and Elbow Flexor Exercise. Built with Sensitive Resistance-Pressure Plate adjustable in height. Calibrated for 0 to 80 lbs.

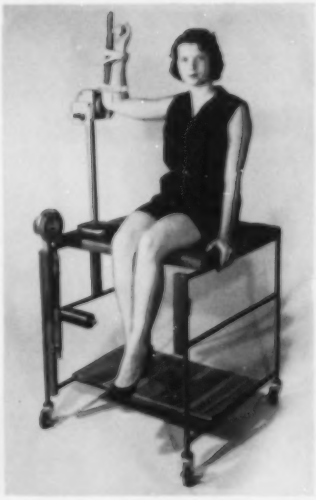
Price including table 28 x 30 x 32

Model # 9952 $159.50

Price without table with bracket for attaching to plinth,

Model # 9952-A $ 89.50

Showing Resistance Control Calibration in pounds. →



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Designed for a complete range of Progressive Resistive Exercise to the Knee Joint Muscle Group WITHOUT THE USE OF WEIGHTS.

Exercise arm built with Reversible Ratchet on Sensitive Pressure Plate offering any desired resistance calibrated in lbs. from 0 to 80. Range of motion indicator in full view of patient and therapist for accurately following Range Progress. Ideal for use with BK Amputees and BK Fractures, may also be used for Hamstring Exercise, Hip Abduction and Extension. Complete unit including table 28 x 30 x 32 with Quadriceps Rest, Model # 9950

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Showing use for BK amputees and fractures. Range of motion dial calibrated in pounds. →

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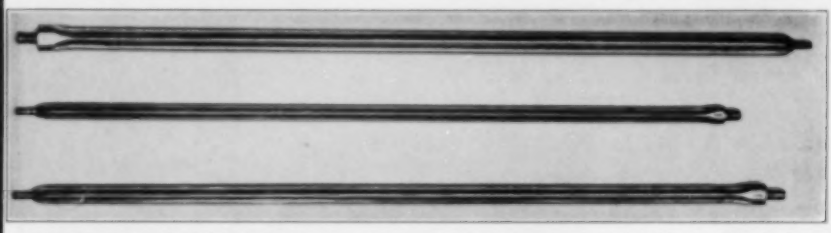
LOTTES NAILS and INSTRUMENTS



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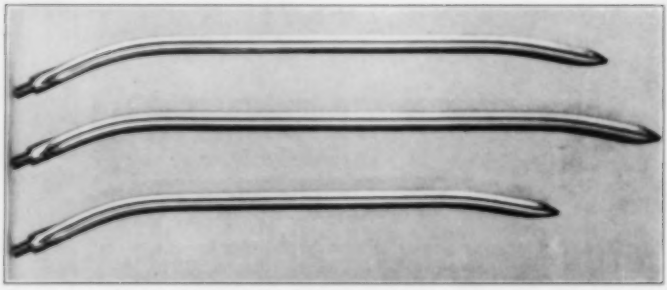

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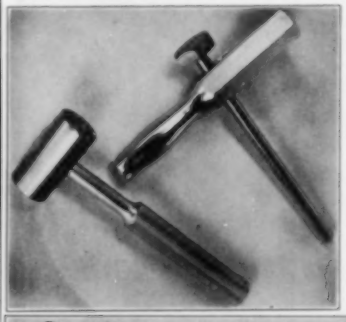
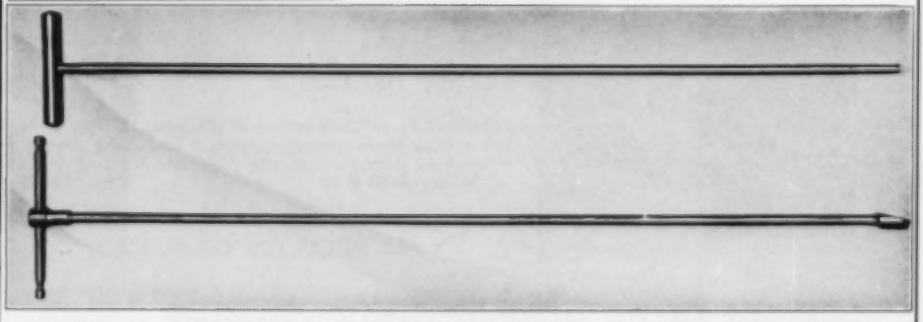


***LOTTES* DRIVER-EXTRACTOR COMBINATION and *LOTTES* MALLET**

***LOTTES* GUIDE WIRE AND *LOTTES* REAMER**

The reamer comes in 3 diameters: 3/8, 7/16, and 1/2 inch—all are 23 inches in length.



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- Kills by contact a wide variety of microorganisms such as *Bacteria (including tubercule bacillus), Viruses, Fungi, Protozoa.* • Effective against certain important organisms resistant to topical antibiotics • Will not lead to the development of resistant strains • Effective even in the presence of blood, pus or other organic matter • Color can be washed off with water.

Available: Betadine Antiseptic in 8 oz. and 16 oz. bottles. Betadine Aerosol in 3 oz. bottles.

Samples and literature upon request.

...YET VIRTUALLY NONIRRITATING TO SKIN AND MUCOSA

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FOR GREATER STRENGTH AND SAFETY—

DEMAND GENUINE NEUFELD NAILS *and* SCREWS

—*IN* NEUTRILIUM®

NEUTRILIUM® is the most non-corrosive metal known to science. Its proven super-strength lends an assurance of permanence to internal fixation of the trochanteric area. This neutral, non-magnetic, homogenetic alloy is entirely inert and therefore compatible with human bone or tissue, remaining unaffected by body chemistry.

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GENUINE NEUFELD NAILS and SCREWS — of ***NEUTRILIUM®*** — made only by MEDICAL RESEARCH SPECIALTIES, Loma Linda, California, are sold nationally by leading surgical and orthopaedic supply dealers.

NEUTRILIUM® *is a registered Trade Name of Medical Research Specialties.*

NEUFELD FEMORAL NAIL PLATE
Used for internal fixation of intertrochanteric and subtrochanteric fractures.
Write for descriptive literature
MEDICAL RESEARCH SPECIALTIES
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Trancopal®

BRAND OF CHLORMETHAZANONE

a completely new major chemical contribution to therapeutics... unrelated to any other drug in current use

- Both a muscle relaxant and a calmative agent.
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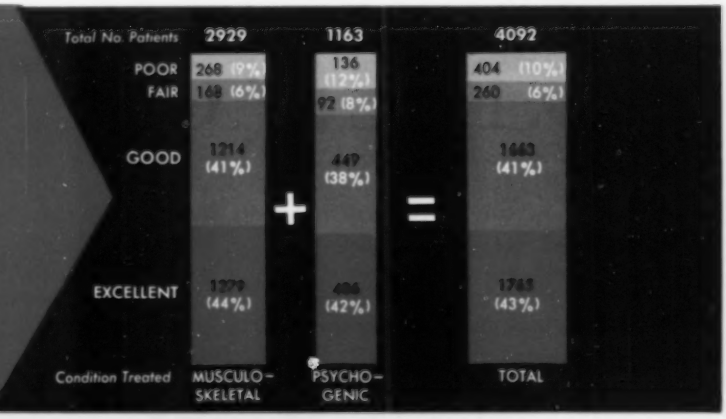
designed to be equally effective as both
a MUSCLE RELAXANT
a TRANQUILIZER

*tran-qui-lax-ant (tran'kwi-lak'sant)
[< L. *tranquillus*, quiet; L. *laxare*, to loosen, as the muscles]

Clinical results in 4092 patients



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MUSCULOSKELETAL
- LOW BACK PAIN (lumbago)
- NECK PAIN (torticollis)
- BURSITIS
- RHEUMATOID ARTHRITIS
- OSTEOARTHRITIS
- DISC SYNDROME
- FIBROSITIS
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- MYOSITIS
- POSTOPERATIVE MYALGIAS

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- ANXIETY AND TENSION STATES
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NEUROLOGIC
- MUSCLE SPASM in paralysis agitans, multiple sclerosis, hemiplegia, poliomyelitis

DOSAGE: One Caplet (100 mg.) orally three or four times daily. Relief of symptoms occurs in fifteen to thirty minutes and lasts from four to six hours.

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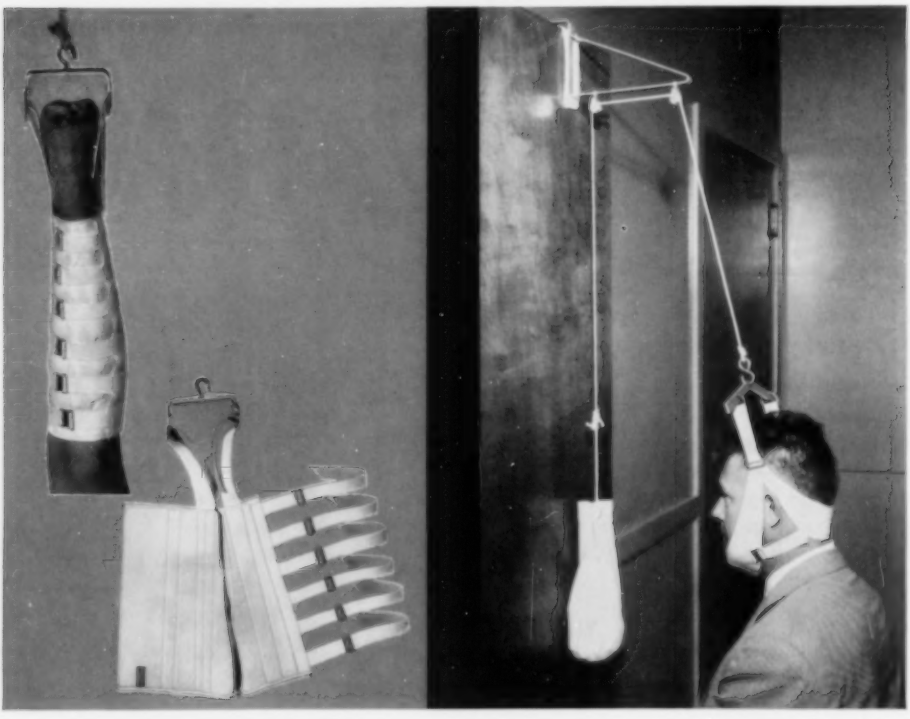
CAMP TRACTION APPARATUS

for positive therapy, comfortable use in hospital or home



CAMP-ANDERSON TRACTION LEGGING

Easy-to-use, one-piece unit

A simple one-piece apparatus for lower extremity skin traction, the Camp Anderson Legging is fabricated with attached straps and buckles so it may be applied by inexperienced hospital personnel. Made from skin-adhering foam rubber covered with soft, strong coutil with an aerated elastic back inset for shaping to the leg. May be washed or autoclaved.

CAMP HEAD HALTER

Available in complete set or individual units

The improved Camp Head Halter is lined with foam rubber vulcanized to strong tackle twill for patient comfort and better fit. Camp's side buckle opening feature permits presetting by doctor or patients for easy donning and removing in the hospital or at home and makes it possible to apply the halter without movement of the patient's head. The notched spreader bar affords use in varying widths.

CAMP TRADE MARK

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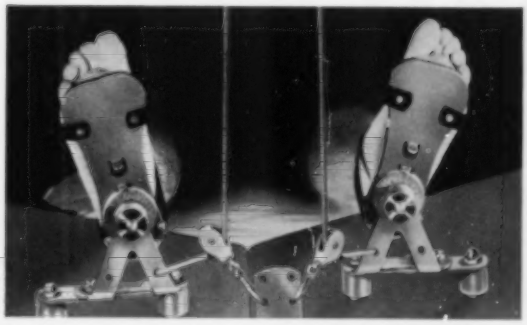
BOWEN FRACTURE APPLIANCES— GREAT AIDS TO BETTER SURGERY



LEG EXERCISER SETS

Designed to assist in passive abduction after cup arthroplasty, rehabilitation of paraplegics, and many other cases requiring weight controlled exercises.

- **Rigid Construction—Relatively Light in Weight**
- **Moves Freely on Ball Bearings in All Directions**
- **Protractor Adjustment for Foot Angle Control**
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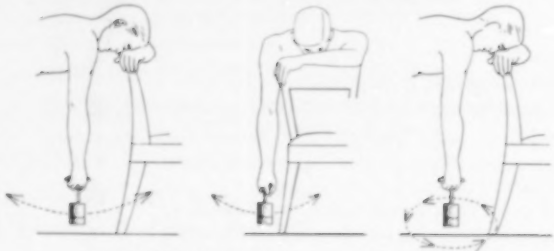
- **Foot and Heel of Exerciser Covered with Foam Rubber**
- **Exercising Board 14" x 48", Hinged at Center and Angled to Approximate the Arc Scribed by the Legs**

ORMANDY PENDULUM EXERCISER

To Prevent Frozen Shoulder

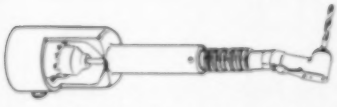
An excellent means to RELIEVE MUSCLE SPASM and PAIN of the shoulder girdle by traction in order to increase the ARC OF MOTION of the scapulo-humeral joint.



Efficient Method of Exercising for Shoulder—Joint Injuries

To Prevent Frozen Shoulder

The compact size of the Pendulum Exerciser will make it possible to increase the arc of motion without hitting the leg of the patient.



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For Luck Bone Saw and Stryker Drill

Designed Especially for the Bankhart Operation

Excellent for bone surgery at difficult angles and in restricted areas requiring use of drills, curetting burrs, slotting burrs. Rigidly constructed, light in weight. Entire unit may be sterilized. Two ⅛ inch diameter High Speed Drills supplied with each attachment.

Easily attached to Jacobs chuck with key.

A hole in the end of the drill bit is provided so that the suture can be threaded and pulled through with the extraction of the drill.

GONIOMETER— Pocket Size Anodized Aluminum

A Pocket Size instrument with calculation flexibility allowing complete angle determination in degrees.

Produced from aluminum, anodized and dyed black, with white-lead-filled dial and indications permitting full penetration of radiation and screening a permanent secondary shadow of measurement on the film for consultations and computations.

BOWEN & COMPANY INC.

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NOTABLY SAFE AND EFFECTIVE INHALATION ANALGESIA

"Trilene"®

Brand of trichloroethylene U.S.P. (Blue)

SELF-ADMINISTERED WITH THE

"Duke" University Inhaler

No. 3160 Model-M

With the "Duke" University Inhaler, "Trilene" analgesia can be self-administered by the patient, adult or child, under medical supervision, with a relatively wide margin of safety. Induction of analgesia is usually smooth and rapid. Inhalation is automatically interrupted if unconsciousness occurs. Outpatients can generally leave the doctor's office or hospital within 15 to 20 minutes.

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In Pediatrics . . . The "Duke" University Inhaler is so easy to operate that even a child can administer his own "Trilene" analgesia.

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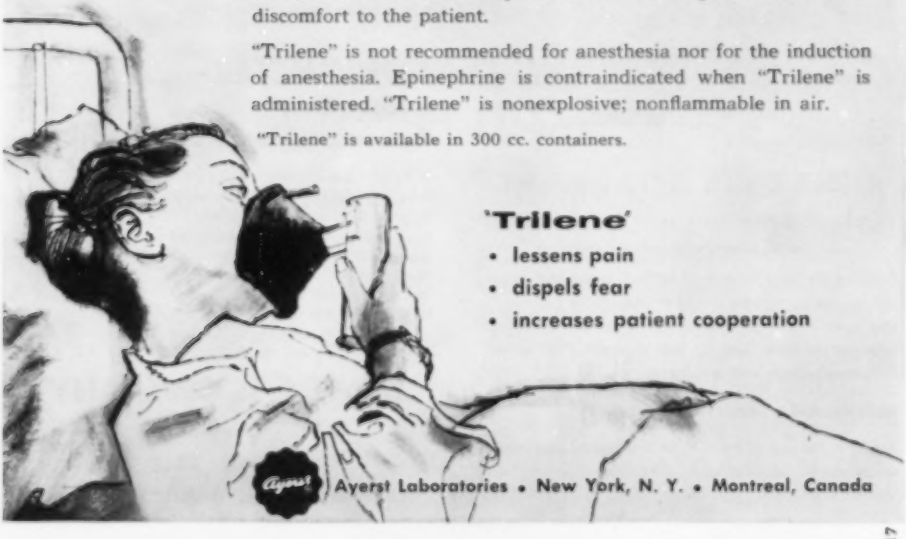
"Trilene" is not recommended for anesthesia nor for the induction of anesthesia. Epinephrine is contraindicated when "Trilene" is administered. "Trilene" is nonexplosive; nonflammable in air.

"Trilene" is available in 300 cc. containers.



'Trilene'

- lessens pain
- dispels fear
- increases patient cooperation

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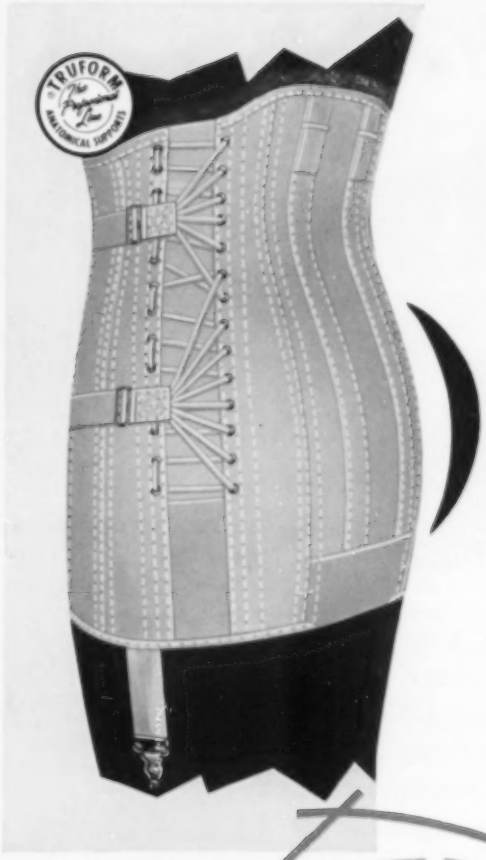


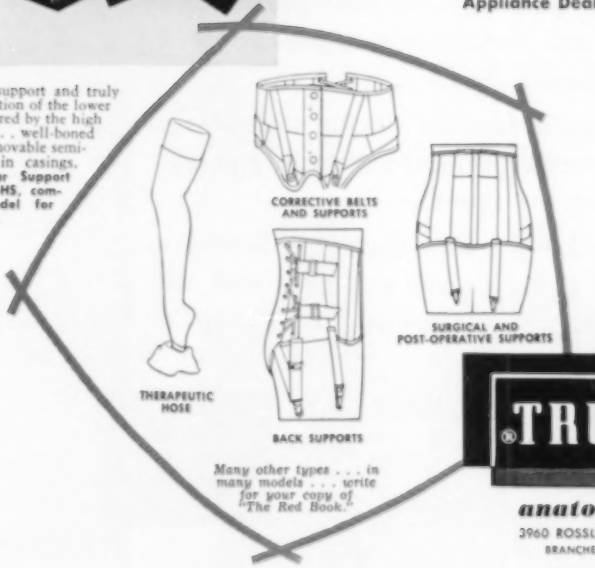
effective FIXATION

Anatomically correct . . . therapeutically sound . . . these principles are designed in, and built in, each Truform appliance.

Effective support or effective fixation . . . this you can depend on when you prescribe "Truform." Your patient benefits from the most careful selection and skillful fitting because . . .

- **TRUFORM Anatomical Supports are available only from the Ethical Appliance Dealer**

Very rigid support and truly effective fixation of the lower spine is assured by the high solid back . . . well-boned and with removable semi-rigid stays in casings. **Sacro-Lumbar Support Model 1165-HS, comparable model for men 447-HS.**



Many other types . . . in many models . . . write for your copy of "The Red Book."

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anatomical supports

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BRANCHES: New York and San Francisco

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SCIENTIFIC CONSTRUCTION SHOES

Style No. 84

Alden-Pedic lasts and shoes are scientifically designed to fit the individual foot shape and at the same time accommodate your prescribed corrections and insertions without sacrificing any fitting qualities. Alden-Pedic shoes are basic prescription shoes. We do not manufacture a pre-corrected or commercial health shoe.

Orthopedic surgeons familiar with the Alden-Pedic program have achieved most satisfactory results in recommending our shoes.

Write us today for our new illustrated brochure of Alden-Pedic styles for men and boys and our new "Progress Report on Shoe and Last Design".

Developed through our modern research program

- Long inside counter
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- Heavy gauge right and left ribbed steel shank.
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Custom Bootmakers Since 1884

BROCKTON, MASSACHUSETTS

FOR BOOKLET AND NAME OF NEAREST DEALER WRITE

PAIN Zactirin®

Ethoheptazine Citrate with Acetylsalicylic Acid, Wyeth

for everyday pain control . . .

for your many patients requiring potent analgesia but not an injected narcotic

Proved by extensive evaluation[1,2,3] in 1998 patients in diverse areas of medicine and surgery, including:

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- *exclusive Wyeth non-narcotic analgesic plus anti-inflammatory action*
- *prompt, potent action—as potent as codeine*
- *documented effectiveness and safety[1,2,3]*

Supplied: Tablets, bottles of 48. Each tablet contains 75 mg. of ethoheptazine citrate and 325 mg. (5 grains) of acetylsalicylic acid.

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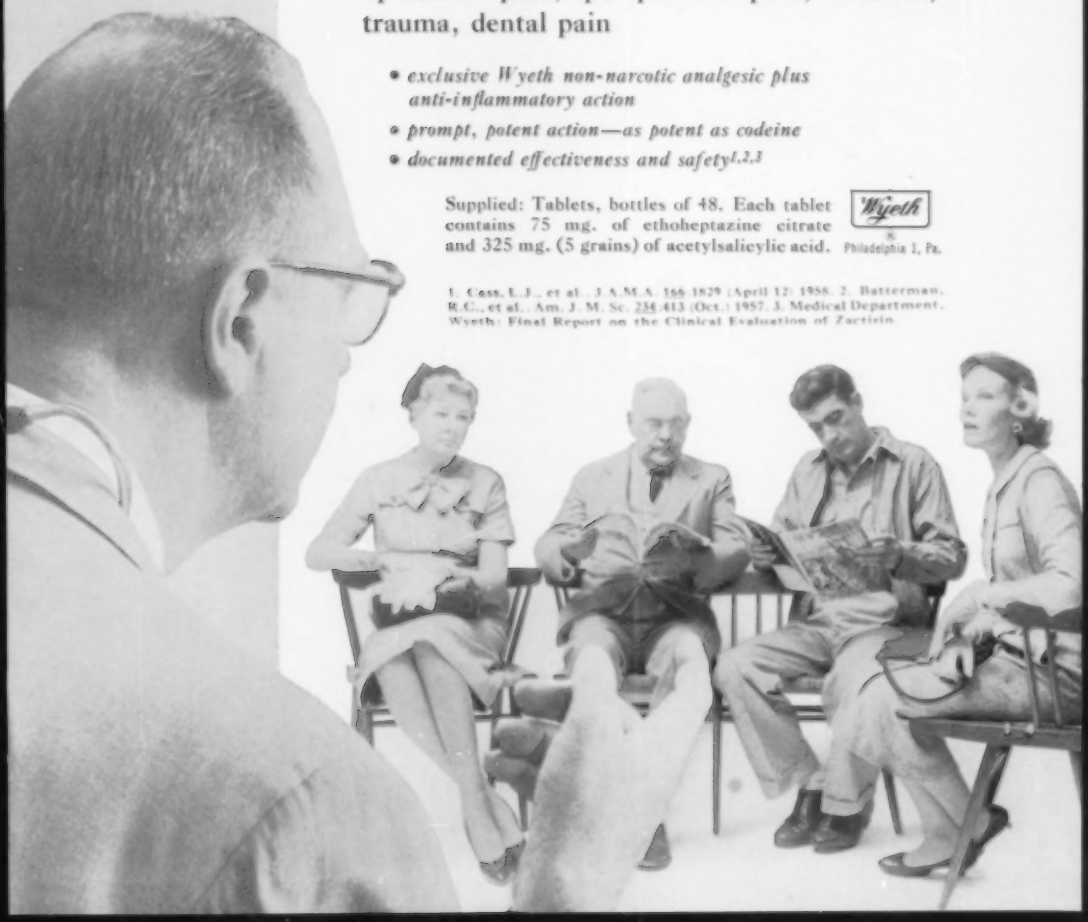
1. Goss, L. J., et al., J. A.M.A. 166:1829 (April 12) 1958. 2. Batterman, R.C., et al., Am. J. M. Sc. 234:413 (Oct.) 1957. 3. Medical Department, Wyeth: Final Report on the Clinical Evaluation of Zactirin



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the hands
that heal
"Specialist"
A DOZEN
EXTRA FAST
PLASTER
BANDAGES
Johnson & Johnson
3" X 3 YD
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VOL. 40-A, NO. 6 DECEMBER 1958

The Journal of
Bone and Joint Surgery
American Volume

Dr. William A. Rogers and The Journal

When Dr. Elliott Brackett died in 1942, he had been the editor of The Journal for twenty years. During that period he had devoted himself wholeheartedly to his editorial duties and had developed The Journal from an obscure specialist's periodical scarcely more advanced than the original Transactions to a magazine of international importance. He had established a tradition of excellence. By devoting his vacations to travel abroad, he had become intimate with the orthopaedic surgeons of England, France, Germany, Italy, and even Russia. In this way he kept his finger on the orthopaedic pulse of the world, and this fact was reflected in the international character of The Journal. To maintain this high tradition was a task so difficult as to daunt anyone less courageous than his successor, William A. Rogers.

Bill, as he was to become affectionately known throughout the Orthopaedic World, was appointed Editor by the Executive Committee of The American Orthopaedic Association in January 1944, more than a year after Dr. Brackett's death. Keenly aware that the mantle of Elijah, which had fallen on his shoulders, had to be worn with becoming dignity and wisdom he at once began a careful analysis of The Journal's affairs. The situation was complicated, the footing treacherous; he had to watch his step carefully. Actually, despite Dr. Brackett's masterful policies, Bill soon realized that as editor he had inherited three problems: first, an unsatisfactory relationship of The Journal to current British orthopaedic literature; second, an insecure financial policy suggesting the need for a commercial publisher, and third, the relationship of The Journal to The American Academy of Orthopaedic Surgeons. Let us see how his eager mind grasped the niceties of each of these, and how, during the next years, he led The Journal through a maze of difficulties to the broad highway of successful publication.

Since 1919, The Journal had been the official publication of The British Orthopaedic Association. Despite this official acceptance, however, the number of papers submitted by the members of the British Association was disappointingly small. This had weighed on Dr. Brackett and he had tried in vain to overcome the lack of active cooperation. Even the Joint Meeting of the British and American Associations in 1929, although very friendly, had not improved the situation. The cause was obvious to anyone willing to look the facts in the face: The Journal had but a small circulation in Great Britain and consequently an article by a British orthopaedic surgeon was practically buried if published in The Journal and did not reach those readers whose interest the author was most anxious to arouse. To Dr. Rogers the solution rested on a radical increase of Journal circulation in Great Britain. Scarcely was he installed in office than he began exploring methods of attaining his end. He broached the subject time and again with intimates on the Staff of The Journal. He discussed it informally with officers of the

British and American Associations. Gradually there crystallized in his mind the concept of a joint publication. By the Spring of 1947 he was ready to act. In May he submitted several alternative proposals to the officers and Editorial Committees of the Association and the Academy, and the Board of Associate Editors of The Journal. At the same time a similar meeting occurred in England. As a result a conference was arranged between representatives of The British Orthopaedic Association and the Editorial Committees of The American Orthopaedic Association and The American Academy of Orthopaedic Surgeons. This took place in London on May 27, 1947. Sir Reginald Watson-Jones acted as leader of the British group, Dr. Rogers of the American. Thanks largely to the admirable spirit of friendliness engendered by those two great personalities, a plan of co-publication was evolved which was approved in June by each of the three organizations. According to this unique plan four issues of The Journal were to be published in the United States, four in Great Britain. Subscriptions could be purchased to both British and American volumes or to each singly. A slight deviation from the original plan of including both British and American issues in each of the two volumes was necessitated by United States postal regulations which require the consecutive numbering of each American issue to secure the benefits of second class mailing. Consequently, two separate volumes were to be published, each bearing the same number, but with the suffix *A* for the American and *B* for the British. The plan was to be tried for a period of three years. A subscription rate of $14 was adopted for the two volumes, $10 for each separately.

To give The Journal still wider scope the British welcomed to their editorial board representatives of the Australian and Canadian Orthopaedic Associations, and later of the South African and New Zealand Associations. The American Board of Associate Editors originally established by Dr. Brackett was increased from five to sixteen members, equally divided between the two American orthopaedic organizations. The first American issue of the joint Volume, Volume 30-A, appeared in January 1948, followed in February by the first British issue of Volume 30-B. The success of the plan was evident from the outset. The Journal offices in London and in Boston worked harmoniously to arrange administrative details. After the three-year period, the plan was approved by both the British and the American Associations. Thus occurred Dr. Rogers first great accomplishment. During all the difficult negotiations, in which the conflicting views of three organizations had to be reconciled, Bill Rogers acted with such modesty, tact, and wise diplomacy that, without swerving from his cherished plan of joint publication, he endeared himself both to his British and American colleagues.

Dr. Rogers had no chance to rest on his laurels; the two other problems pressed for solution. To understand these one must realize that, unlike the conventional editor, Dr. Rogers had to be the business manager of a complicated organization and to attend to its finances as well as to its literary activities. Each year in his admirably concise reports to The American Orthopaedic Association (the owner of The Journal) and to The American Academy of Orthopaedic Surgeons, for which it had been the official organ since 1935, he had had to include a complete financial statement. For many years (since 1929) each member of The American Orthopaedic Association had contributed $15 to a Journal Fund in addition to his yearly subscription of $5. During the period from 1922 to 1929, The Journal had been supported by private donations of varying amounts. These contributions were necessary to publish The Journal in a worthy manner. Members of the Academy, however, had not been asked to make such donations. Each member had paid the usual $5 fee for his subscription, thus giving to The Journal in the year 1947 about $5,000, whereas the actual cost of publishing Academy articles amounted to $15,000. Under these conditions and with the rising costs of publication, it was but natural that The Journal should show a deficit which, in January 1948, came to several thousand dollars.

To the young editor the situation was indeed serious. He lost some of his

usual cheeriness. He looked worried but he never lost faith. During the next few years, while he was struggling to place The Journal on a firm financial footing, his own private life was marked by two significant occurrences, one very sad, the other very happy. In 1949 his older son, who had graduated from Annapolis the year before, was killed in an aeroplane accident while on a training flight. Bill faced the tragedy with amazing heroism and never let it interfere with his devoted work for The Journal, but his friends could see how deep the wound was. In August of 1952 came the happy event: his marriage to his beloved Emily whose understanding and support have helped him beyond measure.

The financial problems of The Journal, which had plagued him ever since he took office, came to a head in June 1948. At the Quebec meeting of the Editorial Committees, the Treasurer of The American Orthopaedic Association voiced the opinion that the "Editor of The Journal should not be called upon to carry the financial load and that the time had come to place the responsibility of the publication of The Journal in the hands of a commercial publisher" (quoted from the Minutes). A motion was carried authorizing the Executive Committee of the Association to appoint a body representative of both the Academy and the Association to explore with a major publishing house the possibility of negotiating a satisfactory contract for publishing The Journal.

To Dr. Rogers this was a hard blow. Although he had confidence in the financial judgment of the Treasurer, his own opinion was directly opposed to commercial publication and he felt that he personally could not continue to function as Editor under such conditions.

At the 1949 business meeting of the Association at Colorado Springs the subject came up for general discussion. Dr. Rogers presented his arguments in masterly fashion. He emphasized that the commercial publisher must be guided primarily by consideration of financial profit, that this was "contrary to the spirit in which The Journal was conceived," that lowering of standards would be inevitable, that control would pass from the hands of The Journal to that of the commercial publisher, that the Editor would be shorn of "all but a mere vestige of control," and that the Association would be giving away a most valuable investment into which it had poured large sums of money and an inestimable amount of energy and effort. Since the subject was controversial many opinions were voiced, but in the end the demand for commercial publication collapsed when the Treasurer suddenly shifted his view and backed Dr. Rogers. The ensuing vote favored continuance of control by The Journal office. Just what was responsible for this turn of events is not known, but perhaps it was due to these words by Dr. Rogers: "In view of my conviction, were I now to sign a contract with a publishing firm to publish The Journal I would be disloyal to the Association. . . . As Editor I have no other choice than to declare my inability to sign such a contract."

Thus ended the second of Dr. Rogers' battles in another complete victory. The price he paid was heavy. He had worked night and day; he had been forced to disagree with trusted friends. In sticking fast to his principles he had to assume a greater responsibility than anyone realized, for The Journal's course was still beset with financial terrors. No one but his most intimate friends knew the travail of his spirit in those days. He had saved The Journal from commercial publication, but how was he going to meet the April 1949 deficit of $9,489.79?

His first step was the creation in May 1949 of The Journal Finance Committee. Through this he hoped to improve not only the finances but also the relationship between The Journal and the Academy. The inequity of the situation was obvious, but even Dr. Brackett had been unable to solve it. Dr. Rogers realized that the essential cause of conflict between the Association and the Academy was the ownership of The Journal by the older organization. The great body of Academy members—enthusiastic young orthopedic surgeons—were anxious to share wholeheartedly in the development of The Journal and felt they were entitled to participate in the publication of this, the official organ of their Academy,

but how could they secure a share in the ownership? Bill kept sounding out the leaders of the Association. Could he not persuade them of the wisdom of relinquishing their exclusive property rights? It was a slow, difficult job, but fortunately his tact and persuasiveness gradually overcame the major obstacles. Working through the Finance Committee a complete reorganization of the ownership of The Journal was evolved in November 1953 and presented to the Association at the Bretton Woods Meeting in 1954. By this The American Orthopaedic Association magnanimously relinquished all rights to The Journal and transferred these to a new corporation, The Journal of Bone and Joint Surgery, Incorporated, controlled by a board of trustees, three representing the Association, three the Academy. These six trustees were to select a seventh who was to be entrusted with the editorship of The Journal. Robert W. Johnson, Jr. whose business acumen was in large part responsible for the details of this plan, was elected Chairman. The Academy, whose membership had been sounded out by a preliminary vote in July 1953, gave its full accord to the plan in January 1954 and contributed the sum of $40,000 to the reserve fund of The Journal, thus creating a total reserve of more than $83,000. Dr. Rogers' financial fears were at last laid to rest, and the conflict between the Association and the Academy had been solved with friendliness, wisdom, and generosity. Only those who know the inside story can realize Dr. Rogers' share in this happy outcome.

But a journal editor has much more to do than to protect the finances of his publication. These are simply means to an end. Actually, his main concern, as phrased by Dr. Rogers himself, is "to endeavor to uphold the standards of The Journal and to maintain its aim—the advancement of orthopaedic surgery." To do this he labored unceasingly. Not only did he read every one of the hundreds of manuscripts submitted, but he maintained a lively correspondence with the authors. Whenever a paper carried the germ of a good idea, however poorly it might have been expressed, Dr. Rogers worked with the author to perfect the paper so that it might attain the high standard required by The Journal tradition. Few readers know how many articles could never have been published had it not been for the able editorial assistance given by Dr. Rogers. In this task he was, of course, aided by the associate editors and by his office staff. Every paper, about which there might be any doubt regarding its suitability for publication, was discussed at the monthly board meetings of the associate editors. It is truly significant that the decision in all cases rested solely on the merits of the contribution. Only once during many years did Dr. Rogers ever show any real anger; this was when an author, disgruntled by the refusal of a paper, wrote a letter accusing the editorial staff of bias in favor of well known orthopaedic surgeons and of disregard of the rights of the "small man." Dr. Rogers strongly resented this insinuation and expressed himself forcibly. It is gratifying to note that this particular author later became one of his staunchest admirers.

Even more important than the careful, honest perusal of every contribution was Dr. Rogers' consistent effort to broaden the scope of The Journal and to solicit papers from those who were doing original work. As a result of negotiations started early in 1947 The Journal became the official organ of the American Society for Surgery of the Hand in February 1950.

It is truly amazing how he managed to keep in touch with active workers everywhere. He had his eyes and ears in every laboratory. Frequently he would surprise a young orthopaedic surgeon by inquiring when he was going to report on such-and-such a research. He was also particularly eager to improve the standards of orthopaedic education by papers dealing with fundamental scientific advances. This effort is reflected in the pages of The Journal. Whereas in 1936 only 5 per cent of the articles dealt with basic sciences, in 1956 the percentage had risen to 22. If a subject appeared to be neglected he would try to stimulate interest in it.

Those associate editors who attended the monthly meetings could not but be impressed by Bill's sterling qualities as Editor: his honesty, his fairness, his thor-

oughness, his indefatigability, his acumen, and his supreme devotion to the advancement of orthopaedic surgery through The Journal. Despite the serious nature of the discussions, he encouraged wit and humor; the meetings frequently lasted many hours but interest never flagged. If Bill ever tired, he never showed even the suspicion of a yawn and he was invariably the last man to leave.

With such a captain at the helm it is little wonder that The Journal has grown steadily in circulation. In 1930 there were a total of 2,128 subscribers. In 1942 there were 3,606, in 1957 there were 10,306. In May 1958 in his report to the Executive Committee of The American Orthopaedic Association he estimated that the circulation of the American volume would exceed 11,500 by the close of the year! Although this growth was in part the expected increment due to the increasing number of orthopaedic surgeons the world over, it was also due in part to his direct efforts. Thus, in 1948 he sent out about 8,000 individual letters to "carefully selected prospective subscribers." At all the important orthopaedic meetings representatives of The Journal were on hand to solicit and accept subscriptions. He never neglected a chance to boost the circulation of The Journal.

The number of text pages has shown a corresponding increase. Thus in 1946 there were 943 pages, in 1957 there were 1,465 pages. The number of issues of the American volume had to be increased from four to six in 1954, and in 1959 there will be eight. This is necessary since otherwise there would be a serious lag in publishing the many articles suitable for appearance in The Journal. The Journal finances are so favorable, thanks largely to his vigorous advertising campaign, that there will be no additional charge for the two extra numbers.

During these years of rapid expansion Bill has maintained the closest and most friendly relations with the British office. Financial problems were readily overcome and both American and British Journals benefited immeasurably because of the joint publication. He saw to it that the natural rivalry was a stimulus to both editorial boards. It is fair to say that Dr. Rogers took a great pride in the excellence of the British publication and he was, of course, justifiably pleased by the praise bestowed on him by the British. There were few honors which he esteemed more highly than the Honorary Fellowship in The British Orthopaedic Association awarded him in July of 1952.

His resignation from the editorship occurred in October of 1958. The British Editorial Board and the American Trustees at their joint meeting named him Editor in Chief Emeritus. He is succeeded by a man whom he groomed for the job—Dr. Thornton Brown. Here again we have an evidence of Bill's wisdom and farsightedness; all too few men in power are willing to admit the inevitability of the day when their power must be resigned. He placed the good of The Journal far above any thought of self, and even in his final act of resignation he thought only of The Journal. All of its readers will regret that he is no longer Editor. They join in expressing to him their unbounded admiration and devotion. He has carried on the Brackett tradition in a manner worthy of his great predecessor and has developed The Journal into the outstanding specialist publication of the world. We, as American orthopaedic surgeons, are proud of Bill Rogers and his great accomplishments. All of us hope that he will be granted many years of health and vigor and that he will see The Journal rise to even greater heights.

LEO MAYER, M.D.

Injuries to Flexor Tendons of the Hand in Children*

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Open injuries of the flexor surface of the hand often result in division of nerves and tendons even though the skin wound appears minimal. In children, division of nerves and tendons is caused most commonly by broken glass or other sharp objects (Table I).

This paper is concerned with the surgical management of sixty children who had tendon or combined tendon and nerve injuries of the flexor surface of the hand. The youngest child was thirteen months of age; the oldest was ten years. All of the patients were operated upon since 1948, fifty-two within the past five years.

TABLE I

CAUSES OF TENDON AND NERVE INJURIES IN CHILDREN

Glass	38
Metal, knives, or razors	12
Tearing lacerations (power saws, hedge cutters, escalators)	7
Crushes (escalators, bricks)	3
Total	60

Eight patients in this series were treated primarily for wounds incurred less than six hours prior to hospitalization. Fifty-six children were operated upon secondarily for flexor tendon or combined tendon and nerve injuries which had occurred from four weeks to six years previously. The secondary operations have been divided into three categories: tendon grafts within the digital sheaths of the fingers, tendon grafts of the thumb, and tendon and nerve repairs of the palm and volar aspect of the wrist.

CLINICAL MATERIAL

Of the sixty children, forty-three were males and seventeen were females. The age distribution is shown in Chart I: over 50 per cent were less than six years of age. Twenty-eight were three years of age or younger. Table II enumerates the procedures employed for the entire series.

Primary Procedures

Eight children were treated initially for injuries involving flexor tendons or tendons and nerves. In two patients, tendon repair was not performed because of the crushing nature of the wounds. Secondary tendon grafts were inserted in the

*Read at the Annual Meeting of the American Society for Surgery of the Hand, New York, N. Y., January 31, 1958.

TABLE II

OPERATIVE PROCEDURES IN SIXTY CHILDREN WITH NERVE AND TENDON INJURIES OF THE FLEXOR SURFACE OF THE HAND

Primary procedures	
Wound closure, no deep repair	2
Suture profundus tendon, finger	2
Suture digital nerves and extensor tendon	1
Suture multiple tendons and nerves, palm	3
	8
Secondary procedures	
Tendon grafts within sheaths, fingers*	34
Tendon grafts of thumb	7
Secondary repair nerves and tendons, palm and wrist	15
	56

*Four were double-tendon grafts and one a triple-tendon graft.

fingers at a later date. Another child sustained a circumferential wound of the ring finger, dividing the extensor apparatus, the volar neurovascular bundles, and the flexor tendons. In this patient the extensor tendon and volar digital nerves were repaired primarily, and a flexor-tendon graft was inserted in the finger three months later. Two children had division of the flexor tendons in the region of the proximal phalanx of the finger. Primary profundus tendon repair was performed in each.

The three remaining children in this group sustained extensive wounds of the palm with division of all the flexor tendons and volar nerves. An infant sustained a sharp laceration, and two older children tearing lacerations. In the infant, primary repair of all divided sensory digital nerves, the motor branch of the ulnar nerve, and all deep flexor tendons was performed. The sublimis tendons and the transverse carpal ligament were not repaired. An eight-year-old child who sustained a power-saw injury of the palm had primary repair of seven volar sensory digital nerves, reduction of an open fracture-dislocation of the fifth metacarpal bone, repair of the flexor pollicis longus tendon, and repair of extensor tendons of the little finger. Further repair did not seem justified because of the impaired blood

TABLE III

AGE DISTRIBUTION IN THIRTY-FOUR CHILDREN WITH TENDON GRAFTS TO FINGERS*

Age in Years	1	2	3	4	5	6	7	8	9	10	Total
Males	2	8	4	2	1	1	2	1	1	1	23
Females	1	4	1					3	1	1	11
Total	3	12	5	2	1	1	2	4	2	2	34

*Four had double-tendon grafts; one, triple-tendon grafts; and three, digital-nerve repairs.

TABLE IV

RESULTS OF FLEXOR-TENDON GRAFTS: FINGERS

Preoperative Condition	Group	Excellent	Good	Fair	Poor	Totals
Good	I	9	6	2	0	17
Scar	II	3	2	0	0	5
Articular	III	0	1	3	0	4
Poor	IV	0	0	0	2	2
Totals		12	9	5	2	28

supply to the digits. The flexor tendons of the fingers had retracted into the forearm; this would have necessitated further incisions and marked prolongation of the operative period. Eight months later, four tendon grafts were inserted from the forearm to the palm. The third patient, a child six years of age, had sustained division of all flexor tendons and digital nerves from a crushing laceration in an escalator. The volar capsules of the metacarpophalangeal joints of the index, long, and ring fingers were avulsed from the proximal phalanges, exposing the heads of the metacarpals. In this patient all sensory digital nerves, the profundus tendons, and the flexor pollicis longus tendon were primarily repaired.

Secondary Procedures

Four of the children in this group had been treated by one of us initially, fifty-two were first seen by us following primary care elsewhere. The earliest secondary operation was undertaken four weeks after injury; the latest six years following injury.

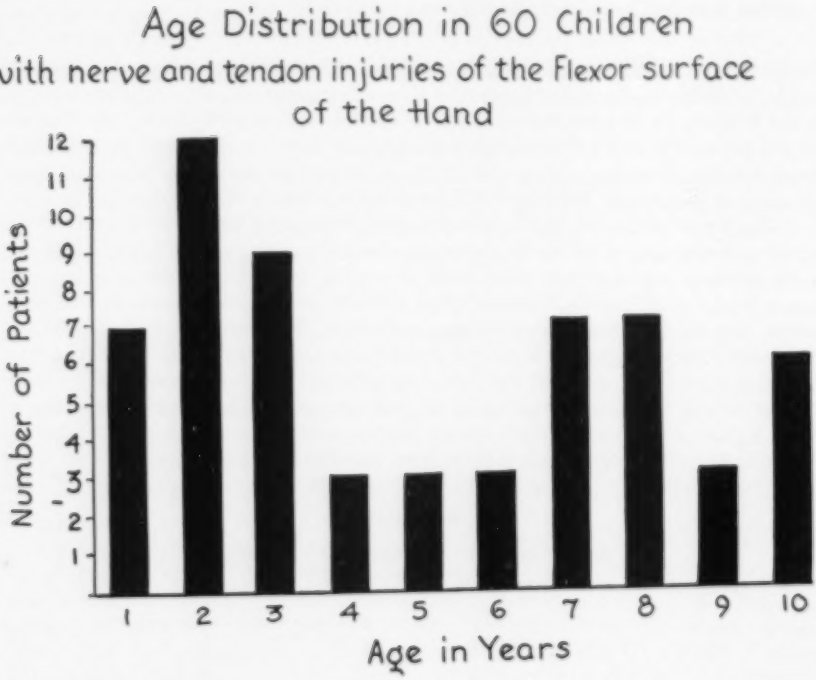

CHART I

A. *Tendon Grafts within Digital Sheaths of Fingers*

Thirty-four patients are included in this category. The age distribution is shown in Table III. Boyes [2] stated that the preoperative condition of the hand must be considered in the evaluation of end results of flexor-tendon reconstruction. Boyes [2], Strandell, and White divided cases in such a category into several groups according to the preoperative condition of the digit. In this series of cases, the *good* group consisted of digits with supple joints, soft minimal scars, and no major trophic changes. The *scar* group included digits with hypertrophied scars of the skin or deep cicatrix limiting passive motion of the digit. The *articular* group included those digits with bone and joint injuries wherein passive motion at the interphalangeal joints was limited. The *poor* group included digits with bilateral

neurovascular lesions, extensive superficial or deep scarring, and marked limitation of passive motion at the joints.

The hands of thirty-four children were classified into one of the above groups. Twenty hands were classified in the *good* group, seven were placed in the *scar* group, and five in the *articular* group. Two hands were classified in the *poor* group.

In the *good* group, sixteen of twenty children were operated upon within three months after the initial injury. None of these patients had undergone primary tendon repair. Twelve had suture of the skin wound, and eight had no immediate medical attention. The case histories revealed that the initial wounds healed without infection.

In the remaining three groups (scar, articular, and poor), six patients had primary tendon repairs performed, two patients had secondary tendon repairs, and two had wound closure without repair. Another child had a severely infected wound following injury. Three children sustained crushing injuries with bone and joint damage. In one child an abdominal pedicle flap was applied to the finger to provide adequate soft-tissue covering over the volar aspect of the finger prior to flexor-tendon reconstruction. Of the fourteen patients in these groups, only four were operated upon for repair of divided tendons within three months following the injury.

B. *Tendon Grafts of the Thumb*

Seven patients are included in this subdivision. Five children had division of the flexor pollicis longus tendon without injury to the branches of the median nerve. The joints of the thumb were supple and scarring was minimal. In addition to division of the flexor pollicis longus tendon, two patients had wounds of the thenar eminence with division of the main trunk of the median nerve as it divided into its motor and sensory branches.

C. *Secondary Repair of Tendons and Nerves in Palm and Wrist*

Fifteen children are included in this category. Six patients sustained injuries to flexor tendons of one digit from palmar lacerations proximal to the digital sheath. One of the six patients had tendon injury without division of an adjacent neurovascular bundle. Eight children had severe injuries of the palm near the level of the transverse carpal ligament and sustained multiple nerve and tendon damage. Primary repair of all digital nerves and the flexor pollicis longus tendon had been performed in one patient. The secondary operation consisted of insertion of four tendon grafts extending from the forearm into the palm. Two patients had single tendon grafts in addition to nerve repair in the proximal portion of the palm or wrist.

Seven patients were operated upon within three months following the initial injury, six within eight months following injury, and one five years after injury.

The children who sustained wounds near the level of the transverse carpal ligament had impairment of intrinsic motion of the thumb. In one patient with ulnar-nerve and median-nerve damage, interosseous and thenar atrophy was evident at the time of the secondary operation.

METHODS

Except for some differences in preoperative diagnostic procedures and in postoperative care, the methods used in tendon or combined tendon and nerve reconstruction in children were similar to those followed in older patients. The criteria for primary repair of flexor tendons advocated by Mason [5] were followed. Age was not considered a contra-indication for either primary or secondary operations in this series. Secondary procedures were performed when passive motion of the joints was maximal and the inflammatory reaction about the wound had subsided.

In all patients, tendon and nerve reconstruction was performed in the operating room. General anaesthesia was given to all patients who had nerve or tendon repair, but local anaesthesia was used to obtain wound closure in the two children in whom no deep repair was undertaken. A bloodless operative field was maintained for dissection and the subsequent repair of the injured structures of the hand. Non-absorbable suture materials were used without exception.

Preoperative Diagnosis in Children

In some hand injuries with small surface wounds, the persistence of profuse hemorrhage rather than the loss of motion compelled parents to seek immediate medical attention for the child. In injuries accompanied by little or no bleeding from the wound, the possibility of a tendon injury was often not suspected until a later date. Case histories revealed eight instances in which no immediate medical

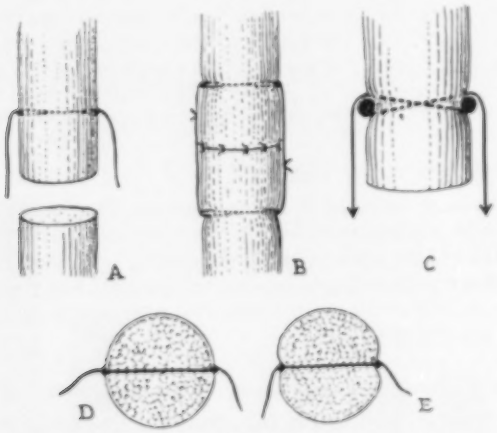

FIG. 1

The technique of tendon repair. (Reproduced from Surgery of the Hand by Michael L. Mason, p. 1176, Fig. 32. *In* Christopher's Textbook of Surgery, Ed. 6. Edited by Loyal Davis. Philadelphia, W. B. Saunders Company, 1956.)

attention was rendered. Broken glass or other sharp objects were the most common causative agents.

Usually the child over six years of age was able to cooperate with the examiner during preoperative tests for motion and sensation distal to the site of injury. Probing of the wounds was avoided in all acute injuries. In most instances, the child under six years of age was unable to cooperate in preoperative examinations. We relied upon observation of the posture of the relaxed hand in the young child to form a preoperative impression concerning the continuity of the flexor tendons of the digits. The value of such observations was noted by Rank and Wakefield. Normally a semiflexed position of the digits is assumed in the relaxed hand because of a tonal balance between intact flexor and extensor muscles. In hands with divided flexor tendons the involved digit does not assume this semiflexed position, and the unopposed action of the extensor muscles maintains the injured finger in extension. It is, therefore, possible to detect division of a flexor tendon to a digit even though the hand is relaxed completely.

Several children with old injuries of the flexor tendons of a finger had learned to grasp the injured finger with a normal adjacent finger, thereby giving the impression that active motion was being performed. The trick maneuver was misleading momentarily to the examiner on several occasions.

Nerve injury in the child under five years of age was suspected frequently by the location of the surface wound, but actual evidence of nerve interruption had to be confirmed at the time of the operative procedure. In older injuries, trophic changes and dryness of the skin were clues to sensory-nerve disturbances. The characteristic deformities and loss of intrinsic motions of the hand which accompany division of the median and ulnar-nerve motor branches were apparent in the children who were examined several months following injury.

FIG. 2-A FIG. 2-B FIG. 2-C

Fig. 2-A: Photograph shows hand of infant, twenty-two months old, attempting to flex fingers three months after sharp injury on volar aspect of proximal phalanges of ring and little fingers. Primary tendon repair had been performed elsewhere.

Fig. 2-B: Photograph shows active flexion of the fingers twenty months following insertion of flexor-tendon grafts into the ring and little fingers.

Fig. 2-C: Photograph shows the extension of the fingers twenty months following flexor-tendon-grafting of the ring and little fingers.

FIG. 3-A FIG. 3-B FIG. 3-C

Fig. 3-A. Photograph shows the attempt to flex the index finger in an infant, twenty-one months old, following sharp laceration in region of proximal phalanx. Injury occurred seven months prior to secondary tendon graft. Primary repair of tendon performed elsewhere.

Fig. 3-B: Photograph showing the ability to flex the index finger independently one year after the insertion of a tendon graft into the digit.

Fig. 3-C: Photograph shows the range of active extension one year following flexor-tendon-grafting to the index finger.

Operative Technique

Adequate anaesthesia, fine instruments and materials, and a bloodless operative field are some of the essential requirements for tendon and nerve repair on the flexor surface of the hand. Adequate exposure is necessary for tendon and nerve reconstruction. Wound enlargement and accessory incisions should be carefully planned to avoid improper healing or secondary scar contractures which would impair the ultimate functional result following repair of the deeper structures.

With the help of a blood-pressure cuff inflated to 280 millimeters of mercury, a bloodless field was maintained while the injured structures were identified and freed. The pressure was then released and bleeding vessels ligated. The extremity

was again elevated for a few moments, the cuff reinflated and the bloodless field maintained until repair was completed, the wound closed, and the compression dressing applied. In patients with severe injury, it was seldom necessary to maintain a bloodless field continuously for more than two hours.

Sutures of 000000 white silk and 000000 ophthalmic silk were used for repair and ligatures exclusively, and 00000 monofilament nylon sutures were used for skin closure.

Primary Procedures

In the acute injuries in which primary repair was undertaken, it was usually necessary either to extend the original wound or to make an accessory incision in order to gain access to the divided structures. Every care was taken to avoid crucial incisions. Incisions perpendicular to flexion creases of the digits or palm were also avoided.

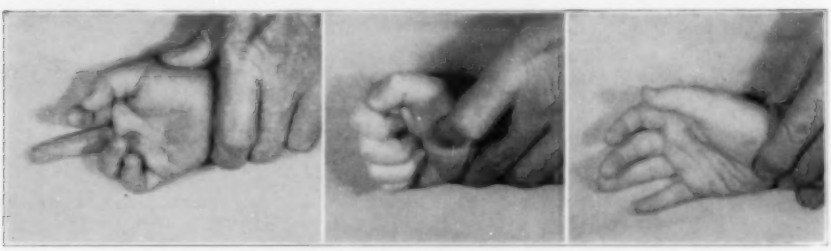

FIG. 4-A FIG. 4-B FIG. 4-C

Fig. 4-A: Photograph shows attempt to flex long finger in child, four years old, injured on sharp metal one month prior to secondary tendon graft. No primary repair had been performed.
Fig. 4-B: Photograph shows active flexion of fingers six months following insertion of tendon graft into long finger.
Fig. 4-C: Photograph shows extension of fingers six months following flexor-tendon-grafting of the long finger.

Divided flexor tendons were repaired by end-to-end approximation according to the technique described by Mason [4]. In injuries to both flexor tendons within the digital sheaths, the profundus tendon was repaired; but the sublimis tendon was removed from the finger. The distal portion of the sublimis tendon was removed at its insertion on the middle phalanx. In order to remove the proximal end of the sublimis from the digital fibrous sheath, an accessory incision was made at the distal flexion crease in the palm. A portion of the fibrous tendon sheath, measuring from 0.5 to 1.0 centimeter, was excised from either side of the site of the profundus repair to prevent interference with tendon healing and subsequent formation of adhesions at this location. An attempt was made to unroof the tendon sheath throughout the whole excursion of the suture line, but every effort should be made to preserve a pulley of sheath over a portion of the proximal and middle phalanges to avoid a bowstring effect. For end-to-end approximation of the profundus tendon 000000 white silk was used for stay sutures and ophthalmic silk for direct apposition of the tendon ends.

In repair of tendons and nerves divided in the region of the carpal tunnel, the nerves and the profundus tendon were repaired; but the sublimis tendons were excised, and the transverse carpal ligament was not repaired. The distal portions of the sublimis tendons were allowed to retract into the palm, and the proximal portions of the sublimis tendons were excised so that they retracted into the lower forearm away from the site of the repair of the nerves and the profundus tendons.

Secondary Procedures

Secondary tendon grafts to the fingers and thumb were performed according to the technique described by Allen. In the finger, a long tendon graft was utilized

from the palm to the distal phalanx. In cases involving the thumb, long grafts were inserted from the distal phalanx to the proximal segment of the flexor pollicis longus at the wrist. The distal attachment of the graft was made on the distal phalanx beyond the joint capsule just proximal to the profundus insertion. A small triangular area of periosteum was removed with a scalpel from the bone, and the graft was placed against the bared bone and overlapped by a short stump of the profundus. Fine silk sutures were used to unite the profundus insertion to the underlying tendon graft which lay against the bare bone. This allowed the graft to unite with the bone on one surface and with the profundus tendon insertion on the other surface. In the palm, the proximal portion of the graft was sutured to the profundus tendon at the level of the origin of the lumbrical muscle. This was done by pulling the graft through the profundus; and, after uniting the smaller graft with the larger profundus, the line of union was smoothed out by drawing the lumbrical muscle around the line of suture.

In children, we used the long extensor tendons of the toes as the source of the tendon graft, except for one patient in whom the palmaris longus tendon of the forearm was used. The tendons used were excised with surrounding paratenon. The normal posture of the hand was used as the guide to help determine the tension of the tendon graft at its insertion into the proximal portion of the profundus tendon in the palm. An attempt was made to slightly overcorrect the normal posture of the digit.

Generally, secondary repair of nerves and tendons at the levels of the palm and wrist corresponded to primary techniques; however, in two patients tendon grafts were necessary to accomplish satisfactory operative reconstruction without undue tension upon the suture lines.

Postoperative Care

The three to three and one-half week period of immobilization after tendon and nerve reconstruction in children was the same usually followed in older patients. Postoperatively, the child's hand was flexed at the wrist and the digits were moderately flexed. Position was maintained by the application of a compression dressing and an aluminum splint. In children under six years of age, plaster molds or casts were applied to the extremity and were extended above the elbow to help maintain the position of the hand during the healing process.

Immunization against tetanus was afforded the children with acute injuries treated by us. In three children with extensive primary repairs in the palmar region, parenteral antibiotics were administered for the first six postoperative days. Antibiotics or topical medications were not placed in the wounds at any time. Postoperative antibiotic therapy was selective in patients undergoing secondary tendon and nerve reconstruction. The decision to give an antibiotic was based upon the duration of the operative procedure or the history of a previous wound infection. Antibiotics were seldom given to patients undergoing secondary tendon-grafting within the digits.

The length of hospital stay following operation in the child from one to six years of age was seldom more than forty-eight hours. For children under five years of age suture removal was performed on the seventh postoperative day under general anaesthesia so as to avoid the struggling which occurs so frequently with suture removal in the young child. When general anaesthesia was to be used, the parents were instructed to withhold food and liquids from the child beyond midnight of the day scheduled for suture removal.

Dressings were changed without anaesthesia at intervals of four to five days during the remainder of the period of postoperative immobilization. Active motion was permitted following the twenty-one to twenty-five days of immobilization. The parents were instructed to wash the child's hand for ten minutes three times a day and to encourage the patient to use his hand without restriction. Formal physical therapy was not prescribed for the children.

In the sixty patients, one postoperative infection occurred as the result of a hematoma of the palm following secondary suture of nerves and tendons. Drainage of the infected hematoma was followed by wound healing without further complications.

RESULTS

In fifty-three of the sixty children operated upon, an opinion was formed concerning the functional return after tendon reconstruction. Follow-up examinations were carried out for several years in some of the younger children prior to establishing the opinion. Results have been classified as excellent, good, fair, and poor in the cases included under secondary procedures. The end results in two cases of primary profundus repair were determined. In children able to cooperate measurements of the degree of active motion of the digits were made with a protractor. In most of the children follow-up photographs were made of the hands and proved to be valuable adjuncts to the examinations.

No difficulty is encountered in the determination of excellent results following tendon reconstruction in children if the criteria advocated by Boyes [2, 3] are employed as a part of the examination. Our interpretation of an excellent result is one in which the pulp of the affected finger can touch the distal crease of the palm, and in which, as White has suggested, the patient can extend the finger completely. In cases involving the thumb, voluntary flexion at the interphalangeal joint is compared with passive flexion; and, if no difference can be detected, the result is excellent. In this series of fifty-two patients, a good result was one in which at least 75 per cent return of function was evident. Fair results were those in which at least 50 per cent return of motion was present.

Results of Primary Repair

Primary profundus-tendon repair within the digitals sheaths yielded one good result and one fair result in two patients. The interval following repair was too short to assess the results of the three patients with extensive palmar injuries, but satisfactory progress in the return of function was observed. The infant was examined recently, one year after operation, and active flexion could be performed in all digits. The size and the nutrition of the hand operated on was comparable to that of the opposite hand, but the child did not use his hand voluntarily to grasp objects. No measurements were made because of his inability to cooperate.

Results of Secondary Repair

Follow-up examinations were made in forty-eight of the fifty-six patients included in this group. In twenty-three patients, excellent results were obtained, and in seventeen patients good results followed secondary reconstructive procedures to flexor tendons and nerves.

A. *Results of Tendon Grafts in Fingers*

Of thirty-four children in this category, twenty-eight were followed for intervals long enough to establish an opinion concerning the end result of the tendon-grafting. The criteria set forth by Boyes [2, 3] and White were followed to determine the excellent results. Twelve excellent and nine good results were obtained after tendon-grafting within the digital sheaths of the fingers. Table IV lists the end results and correlates the effect of the preoperative condition of the hand upon the outcome after tendon-grafting procedures.

B. *Results of Tendon Grafts of the Thumb*

Five excellent and two good results were obtained following the insertion of long tendon grafts into the thumb in children.

C. Secondary Repair of Nerves and Tendons of the Palm

Follow-up studies were made in thirteen of the fifteen children operated upon within this category. Six results were considered excellent, and six were good. There was one fair result after the reconstructive procedures in the palm of the hand.

COMMENT AND SUMMARY

This presentation relates our experience with sixty children who sustained tendon injuries or combined tendon and nerve injuries of the flexor surface of the hand. Sixty-four operative procedures were performed in this series of cases. Primary repair of divided flexor structures was undertaken in five patients, and in fifty-six patients secondary reconstructive procedures were performed. The majority of the patients were less than six years of age. Operative techniques in children were the same followed for older patients. The preoperative diagnosis of tendon injuries in the child too young to cooperate was not difficult provided careful observations of the posture of the hand were interpreted properly. In the young child, nerve injuries could be suspected by the location of the surface wound. However, the absolute identity of nerve interruption had to be confirmed at the time of the operative procedure.

The secondary procedures included tendon grafts within the flexor sheaths of the fingers and thumb, and repairs of multiple nerve and tendon injuries in the palm. Thirty-four children had tendon grafts inserted into the fingers. Of the latter group, 65 per cent were less than six years of age. Seven patients had tendon grafts of the thumb and fifteen had secondary repairs for injuries in the palm. Although the structures are smaller in the child's hands, the operative procedure was often less difficult than in the adult hand. In the majority of the cases, the interphalangeal joints were supple and scarring was less than in the older patients. In most of the children the long extensor tendon of a toe was used for grafting.

The maintenance of postoperative immobilization of the hand challenged us frequently in the child under six years. In the child too young to cooperate, suture removal was carried out under general anaesthesia. Formal physical therapy was not prescribed for children.

Follow-up examinations were continued at yearly intervals in many of the young children before the end result could be ascertained. Fifty-three children were included in the follow-up study. In children of different ages, the variance in hand size precluded the use of measurements other than degrees of active and passive motion. The influence of the preoperative condition of the hand upon the result following tendon reconstruction should be stressed. Excellent results following tendon repair in children were determined according to criteria set for older patients. However, lesser stages of functional return were assessed with more difficulty. In fifty-three patients, twenty-three excellent and eighteen good results were obtained after either primary or secondary tendon and nerve reconstruction on the flexor surface of the hand.

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DISCUSSION

DR. JOSEPH H. BOYES, LOS ANGELES, CALIFORNIA: I think it should be noticed that a relatively small number of primary repairs were done. This means that a careful selection was made of cases for primary repair. Of thirty-four patients seen in whom tendon-grafting was done, twenty had no trophic changes. In twelve of these, simple skin closure had been done. This is important because the result of secondary reconstruction of the flexor tendons depends almost directly upon the condition of the finger. The least that is done at the time of the accident in attempting to repair the tendons, the less scarring there will be and less problem with secondary reconstruction.

He also did not have time to point out that some of the factors which determine what must be done at the time of injury are the type of wound (lacerated or crushed) and the facilities available for repair. Repairs cannot be done in the first-aid room. Another factor is the location of the wound.

I would like to bring in two points on secondary tendon grafts in the finger. Dr. Bell pointed out that the use of the extensor of the toes in children and the palmaris longus in adults was desirable. We prefer the palmaris longus. Several years ago I made the point that we had better results when the palmaris longus was used.

We are not trying in flexor-tendon-grafting to reproduce tendon-sheath mechanics. What we are trying to do is to produce a gliding tendon in paratenon tissue. At the time of reconstruction all the remaining sheath can be dissected out so that there will be a tendon graft with a good blood supply and, in subcutaneous tissue, better mechanism will result.

Dr. Bell also made the point in his paper of his bringing these children back at nine and twelve days for removal of the sutures, which they do under general anaesthesia. We gave it up some time ago. I do not think one is justified in assuming that additional risk when catgut sutures in children are easily removed.

Rheumatoid Tenosynovitis

DIAGNOSIS AND TREATMENT

BY T. A. POTTER, M.D., AND J. G. KUHNS, M.D., BOSTON, MASSACHUSETTS

From the Robert B. Brigham Hospital, Boston

Involvement of the tendons and tendon sheaths is relatively common in rheumatoid arthritis. This type of lesion is encountered most frequently in the so-called non-specific tenosynovitis. In arthritis clinics, most of the patients with active rheumatoid arthritis will have such lesions at some period in the disease. The inflammation of the tendon sheath may be present for a long time without producing any symptoms. Unless the patient has active rheumatoid arthritis, the lesion is often misdiagnosed at first. The tendons and sheaths most commonly affected are those of the extensor tendons about the wrist and the ankle, but rheumatoid tenosynovitis has been seen in many other areas.

This condition was first recorded by Scudamore in 1827 in patients suffering with rheumatism. Stockman in 1904 described a tendon inflammation which he called tendinous rheumatism. Snapping tendons were mentioned as a common finding in rheumatoid arthritis by Helweg in 1924. Kahlmeter in 1933 found nodules on the tendons of patients suffering from rheumatoid arthritis. Edström in his studies of the disease found such involvement of the tendons in 48 per cent of 391 arthritic patients. In 1950, Kellgren and Ball reviewed one hundred patients suffering from rheumatoid arthritis and found lesions on the tendons in 52 per cent of them. Operations upon fifteen of these patients showed nodules on the tendons, adhesions between the tendon and the tendon sheath, fibrous thickening of the mesotenon, and fibrinoid degeneration within the tendon sheath.

The course of rheumatoid tenosynovitis is very slow. It usually begins without pain or other noteworthy symptoms. In a tendon surrounded by a definite sheath, painless swellings appear along the course of the tendon. These swellings are rarely seen when there is no evidence of activity of the disease. Although there may be spontaneous regression or disappearance of the swelling, the usual course is one of progressive enlargement. Fibrosis occurs with binding down of the tendon by adhesions. A small number progress to degeneration and replacement of the tendon with granulation tissue. Such tendons may rupture from muscular contraction or from minimal external trauma.

FIG. 1

Rheumatoid tenosynovitis with swelling arising from extensor tendons of the hand in a woman fifty-five years old. This had been enlarging slowly for four years before operation.

Microscopic examination of these swellings shows proliferation of fibrous tissue in the lining of the tendon sheath and infiltration with small round cells. The tendon sheath is distended with increased fluid (Fig. 1). Often a fluctuant swelling is localized to one portion of the tendon sheath by adhesions. Degeneration of the tendon sheath may occur with accumulation of detritus, cholesterol, and rice bodies within the tendon sheath. Pannus grows from the sheath onto the tendon and granulomatous nodules appear both on the tendon sheath and on the tendon. Both pannus and nodules cause impairment of the blood supply to the tendon. There is ischaemic necrosis with replacement of the tendon with fibrous tissue. Adhesions to the surrounding tissue or rupture of the tendon are the final result.

The diagnosis is usually made on clinical examination. Occasionally it can be established only by pathological examination of the tendon and tendon sheaths. The disease can be suspected in a patient with active rheumatoid arthri-

tis. We have never seen it without accompanying articular symptoms. In our early cases, tuberculous tenosynovitis, a ganglion, a herniation of the articular capsule, a tumor, or a muscle lesion were suspected. All of these must be considered in the differential diagnosis since they may be found in patients with rheumatoid arthritis. In rheumatoid tenosynovitis, the swellings are usually located on the dorsum of the hand between the radiocarpal joint and the distal end of the metacarpal shafts. The swelling moves with the tendon in muscle contraction. It is not painful and there is no crepitation. Roentgenograms show only soft-tissue swelling; calcification has not been observed. These findings in a patient with rheumatoid arthritis make one strongly suspect rheumatoid tenosynovitis. If surgery is contemplated, diagnosis should be confirmed by biopsy. Examination of the tendon sheath or tendon will show rheumatoid nodules, except in the very late stages when granulation tissue and necrosis may be the

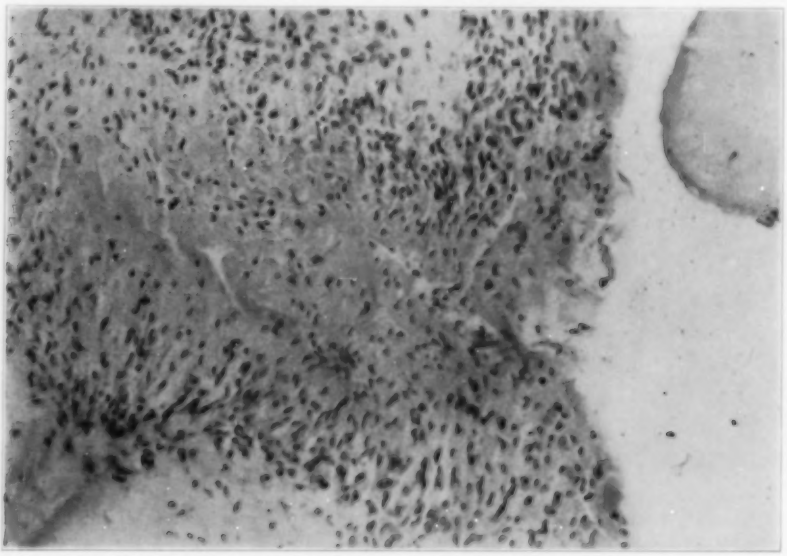

FIG. 2

Wall of tendon sheath (× 600). There is synovial proliferation with round-cell clusters about blood vessels. A rheumatoid nodule with central necrosis is seen in the central portion of the figure. A ricelike body is at upper left corner.

only findings (Fig. 2). The finding of rheumatoid nodules in the tendon sheath or tendon is the only certain way of making a diagnosis.

Treatment depends upon the size and the duration of the swelling. When the swelling is small, less than one-half inch in diameter, that portion of the limb is put at rest with a removable plaster splint holding the tendon in a relaxed position. Splints are worn at night until the swelling subsides. Heat is applied to the involved area for periods of one-half hour, twice a day. Exercises for the finger and wrist are carried out to improve the circulation, to preserve the function of the tendon, and to prevent adhesions. Such treatment is carried out when we have presumptive evidence that the patient is suffering from rheumatoid arthritis. Otherwise a biopsy is performed before treatment is started. If the swelling remains unchanged after several weeks of such treatment, twenty-five milligrams of a solution of hydrocortisone is injected into the swelling with sterile technique. Such injections, repeated every two weeks, have frequently led to a complete disappearance of the swelling.

In larger swellings, over an inch in diameter, more vigorous measures are usually required. The most effective measure is to remove all of the involved

tendon sheath and any granulomata found on the tendon. In about one-half of the patients, this seems to stop the process completely; in the others, it delays or prevents degeneration and rupture of the tendon. In a few patients, the operation has had to be repeated; but, in most instances, removal of the diseased tissue leads permanently to subsidence of the process. The dissection of diseased tissue is carried as far as there is swelling or adhesions about the tendon.

When the tendon is restricted in its motion or when there is no motion, adhesions in the tendon sheath or rupture of the tendon must be suspected; these are usually confirmed at operation [5]. Adhesions within the tendon sheath are freed, but usually the tendon is seriously damaged by invasion of the arthritic granulations (Fig. 3). When rupture of a tendon has occurred only operative repair will improve function [4]. This may consist in resection and suture of the

FIG. 3

Rheumatoid granulation tissue surrounding and invading the extensor digitorum communis tendons. The tendon sheaths and surrounding massive swellings have been removed. Such tendons rupture with minimal trauma.

tendon ends if they are not seriously invaded by the granulation tissue. If the tendon is seriously involved, suturing will be of little avail; separation of the tendon at the suture line or at the weakest part of the tendon will soon occur. In such instances the diseased portion of the tendon should be removed until healthy tendon is found. A tendon graft should be substituted for the diseased portion of the tendon [12]. The results of any of these procedures, while usually helpful, have been much less gratifying than those observed in the traumatic separation of tendons. Our best results have been in tendon transfers, for example, the indicis proprius to the extensor pollicis or the extensor carpi radialis to the extensor digitorum communis.

The general principles of treatment are the same as for other lesions in rheumatoid arthritis. Rheumatoid tenosynovitis in the early stages responds to treatment much the same as articular lesions do. Its rate of progression decreases with improvement in general health. It responds somewhat to rest and support, to physical therapy, and to steroids. Occasionally spontaneous remission of the tenosynovitis has been observed. In many instances, however, slow

progression of the lesion occurs despite treatment. Table I shows the results of treatment in patients with rheumatoid tenosynovitis who have been followed longer than one year. Only small swellings, less than one-half of an inch in diameter, were treated conservatively with heat and support. In most of these, the diagnosis was not verified by biopsy. There were sixty-five patients so treated. Thirty of these have been cured, that is, the tenosynovitis has disappeared and has not recurred. In ten, the lesion has become smaller but is still present; in twenty-five there was no response to treatment.

TABLE I

TREATMENT OF RHEUMATOID TENOSYNOVITIS

Type	No.	Cured	Improved	Unimproved
Support and heat	65	30	10	25
Injections of hydrocortisone	35	15	5	15
Excision of swelling	30	20	3	7
Repair of tendons	24	10	2	12

Circumscribed lesions not larger than an inch in diameter were treated by injection of hydrocortisone repeated at two-week intervals. Thirty-five patients were treated in this manner. Fifteen of these showed complete disappearance of the swelling, five were improved, and fifteen were not influenced by the treatment. Masses on the tendons larger than an inch in diameter were excised. There were thirty patients with such lesions. Twenty patients were relieved completely and had no recurrence, three had a slight recurrence of the swelling, and seven soon had full recurrence of the lesion. It should be stated that it was not always possible to remove the granulomatous tissue entirely since this would have required sacrificing essential anatomical structures. Tendon repairs including resuturing, grafting, and transferring of tendons were performed in twenty-four patients. In ten of these the operation restored good function. Improvement in function was observed in two patients. In twelve no improvement occurred. It is difficult to give figures of cure or improvement in rheumatoid tenosynovitis since the disability in these patients is not static and the rheumatoid arthritis usually presents frequent exacerbations and remissions.

The question has been raised whether rheumatoid tenosynovitis is allied either in etiology or in pathological manifestations to de Quervain's disease [8] or to snapping-finger [2]. We believe that the relationship between these lesions is only an incidental one probably associated with local trauma. In rheumatoid tenosynovitis one always finds granulomatous tissue within and upon the tendon sheaths with rheumatoid nodules in the pathological tissue. In de Quervain's disease and in snapping-finger these changes are never found; one finds only mild thickening and narrowing of the tendon sheath with occasionally increased vascularity and round-cell infiltration [10]. Localized constriction of the tendon sheath associated with bulbous swelling of the tendon distal to the stenosis of the sheath is one of the characteristic findings. With rheumatoid arthritis, particularly in patients subjected to repeated trauma about the hands, we see constrictive tenosynovitis both in the sheath of the abductor pollicis longus and extensor pollicis brevis and also in the sheaths of the flexor tendons of the thumb and fingers. We are unable to state that such constrictive tenosynovitis occurs more frequently in patients with rheumatoid arthritis than it does in the over-all population. We have no reason to believe that de Quervain's disease and snapping-finger are a manifestation of rheumatoid arthritis. From our own observations and data of others, we conclude that these forms of tenosynovitis are most frequently the result of trauma with possibly an associated degenera-

tion of fibrous tissue. They have no direct relation to rheumatoid arthritis and are not related to rheumatoid tenosynovitis.

SUMMARY

1. Rheumatoid tenosynovitis is a common complication of rheumatoid arthritis. Its slow, non-painful development often results in failure of recognition and diagnosis.

2. This lesion is found most commonly on the dorsum of the wrist, involving the extensor tendons. Diagnosis can be established only by histological examination of the diseased tissue. It can be suspected when swelling appears in and upon the tendons in the presence of rheumatoid arthritis.

3. Treatment in the early stage should include heat, support, and relaxation of the tendon. It may be supplemented by injections of hydrocortisone into the mass every two weeks. When the swelling becomes large, excision of the diseased tissue as completely as possible is advised. Rupture of tendons requires surgical repair.

4. In early tenosynovitis, rest and heat resulted in complete relief in 46 per cent of the patients. In masses less than one inch in diameter injections of hydrocortisone led to rapid disappearance of the mass in 43 per cent. Excision of masses greater than one inch in diameter resulted in cures in 66 per cent. Tendon repairs led to good function in 44 per cent.

5. No relationship could be established between rheumatoid tenosynovitis and de Quervain's disease and snapping-finger.

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Tenosynovial Osteochondroma in the Hand

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Osteochondromata arising from or intimately associated with bone are common. Such tumors occurring independent of bone are rare and the pathogenesis is less easily understood. The rarity of recorded cases of soft-tissue osteochondroma in the literature warrants the reporting of two cases of osteochondroma arising from the tenosynovial tissues in the hand. The recorded cases of tenosynovial osteochondroma show that there is a predilection for hands rather than feet and for flexor-tendon sheaths rather than extensor tenosynovial tissues. There is no evidence suggesting that these tumors are other than benign or that they recur after removal.

In 1923 Buxton reported the case of a violinist with a calcified chondroma in the palm attached by a pedicle to the radial side of the flexor-tendon sheath of the ring finger. Another case was that of a calcified chondroma attached to the flexor-tendon sheath of the index finger. He also described a specimen (1569, Old Catalogue), in the Museum of Kings' College Hospital, London, which has several tumors attached to a tendon sheath. Examination showed these tumors to be composed of fibrocartilage. In regard to origin, Buxton supposed that cells capable of producing cartilage had strayed from their primitive basis in bone and had become attached to connective tissue. In 1927, Janik reported a calcified cartilaginous tumor the size of a hen's egg attached to the sheath of the long flexor tendon of the thumb in a woman twenty-four years old. Lewis, concerning tumors of the tendon sheaths, wrote that benign osteochondromata may develop independent of bone just above the point where the tendon inserts, where precartilaginous tissue usually persists in the tendon. Morton, correlating the biological relationship of tumors of tendon sheaths, joints, and bursae discussed the possibility that the synovial

FIG. 1-A

FIG. 1-B

Oblique and lateral roentgenograms show a calcific density overlying the radial aspect of the wrist.

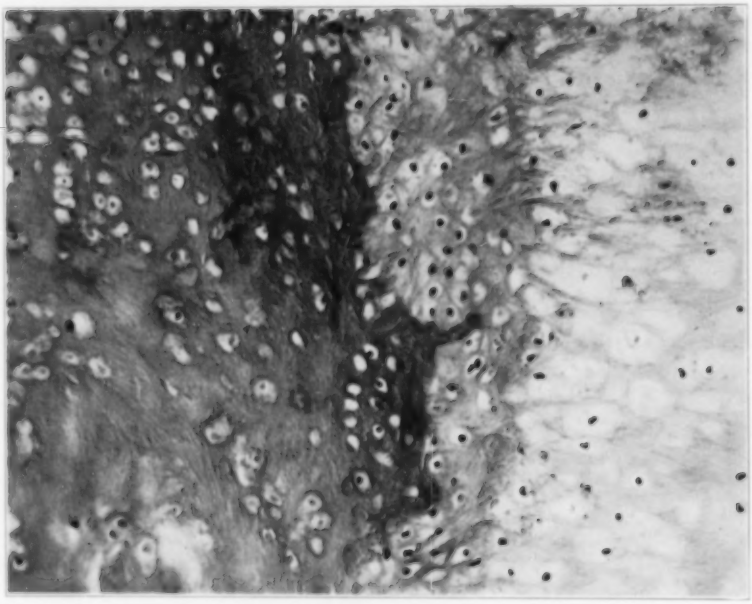

Fig. 3

High-power photomicrograph (× 250) demonstrating the transition zone at the periphery of the tumor where cartilage is calcifying and osteoid tissue forming.

Fig. 2

Low-power photomicrograph (× 125) showing a portion of a nodule composed of hyaline cartilage with a periphery of osteoid tissue and a fibrous capsule.

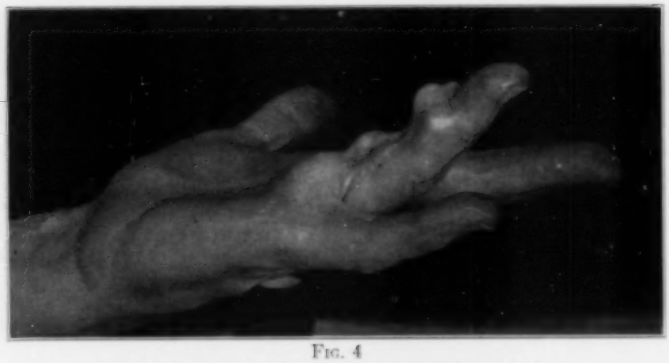

FIG. 4

Photograph of the involved finger prior to excision of the lesions.

cell reverts to a primitive type of connective tissue closely related to cartilage and bone cells. Under unknown conditions such a cell may undergo metaplasia in the direction of cartilage and bone. Shepherd, in his article of 1942, reported a case of osteochondroma attached to the flexor-tendon sheath at the level of the proximal crease in the index finger. The tumor was three-eighths inch in diameter, the nearby tendon appeared healthy, and the microscopic section displayed hyaline cartilage with bone formation confined to a few central areas. Geschickter and Copeland in their discussion of rare benign tumors of tendon sheaths indicated that benign osteochondromata may arise within the tendon sheaths independent of bone. Of the seven cases of their series, one occurred on the flexor surface of a finger. It was found that calcification and ossification appeared beneath the capsule of the cartilaginous lobules. The cycle of histological changes observed in these tumors was from connective tissue to cartilage and finally to bone, thus repeating the histogenesis of intracartilaginous ossification.

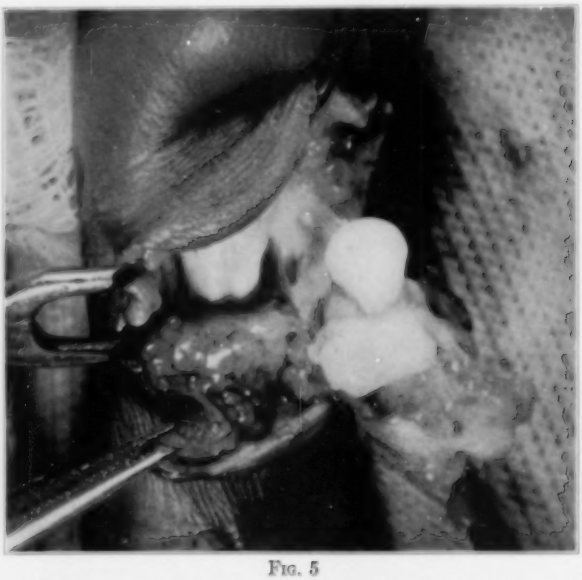

FIG. 5

The attachment of the tumor to the flexor-tendon sheath as seen at operation.

The following case reports illustrate examples of tenosynovial osteochondromata in the hand.

CASE 1. A woman office worker, fifty-two years old, who was right-handed, was struck at the base of the right thumb by a filing-cabinet drawer. Several days later she noted a freely movable nodule over the dorsum of the base of the thumb. The mass was moderately tender and symptoms of local pain, aggravated by use, increased until she sought medical attention four months after the accident. Examination revealed a freely movable, firm, tender nodule lying adjacent to the short extensor tendon on the radial side of the right thumb. Roentgenograms (Figs. 1-A and 1-B) revealed calcification in the soft tissue overlying the radial aspect of the right wrist joint. At surgery an osteocartilaginous mass 0.5 centimeter in diameter was found lying along the course of the long abductor tendon of the thumb attached to the tendon sheath by a three-quarter inch villiform pedicle. Grossly the specimen consisted of a round, firm, gray-white nodule four by six millimeters. The surface was smooth and partly calcified. Microscopic examination (Fig. 2) indicated that the nodule was mainly composed of hyaline cartilage with a periphery of osteoid tissue. The transition zone at the periphery of the tumor where cartilage was becoming calcified and osteoid tissue forming was noted (Fig. 3). Recovery was uneventful and at ten months there had been no recurrence.

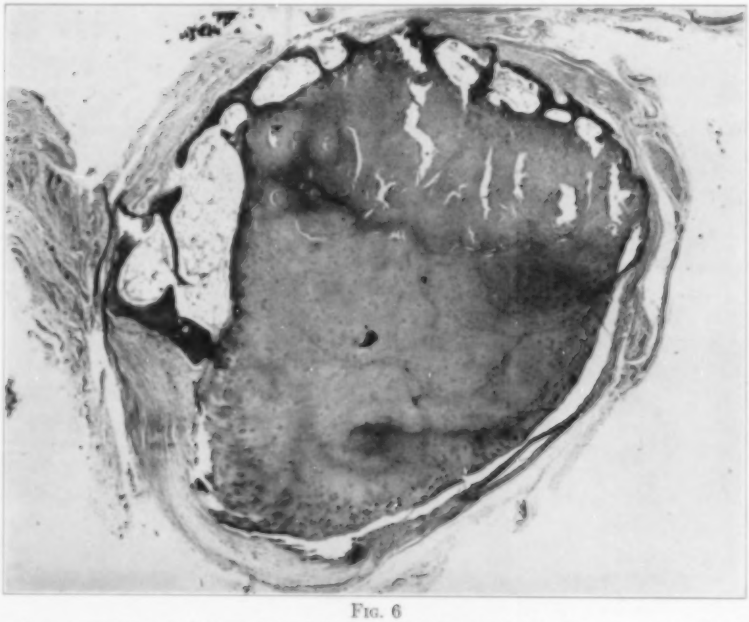

FIG. 6

Low-power photomicrograph (× 20) demonstrating a nodule of the tumor composed of a fibrous capsule, cartilage, and a peripheral area of bone.

CASE 2 (patient of Dr. Joseph H. Boyes). A housewife, sixty years old, right-handed, received a contusion of the left ring finger from striking it on a steel rack in 1918. Several months later a hard movable mass was noted on the volar aspect of the finger. It was excised on three separate occasions, in 1920, 1923, and 1926. The tumor recurred, over the following fifteen-year period, probably due to incomplete excision. On our first examination, in June 1955, there were multiple tumors of the volar surface of the left ring finger (Fig. 4). A mass was found in the middle segment on the radial side of the ring finger originating from the flexor-tendon sheath (Fig. 5). Grossly there were four irregular lobulated pieces of cartilaginous tissue. The photomicrograph (Fig. 6) demonstrated a nodule of the tumor composed of a fibrous capsule, cartilage, and a peripheral area of bone. The wound healed by primary intention. Three years and six months later there had been no recurrence.

DISCUSSION

In reviewing these two cases, some of the features that warrant emphasis are

the following. Both patients were adult women. Neither gave a family history of a similar condition. Both gave a history of trauma preceding the onset of symptoms referable to the tumor. The outstanding feature on physical examination was the presence of a firm, movable nodule that was slightly tender. The preoperative roentgenogram in one of the cases showed a calcific density lying in soft tissue. In each case surgical exposure revealed a smooth-surfaced firm tumor with a pedicular attachment to the tendon sheath. The fibrous, cartilaginous, and osseous components of these tumors were confirmed by microscopic examination. The tumors in this series were benign.

The role of trauma in the pathogenesis of this tumor is speculative. In our series of cases, it is probable that trauma precipitated a focus of irritation directing the patient's attention to the area of tumor growth. The fibrous, cartilaginous, and osseous components of this tumor seem to indicate that tenosynovial cells possess multipotential variations.

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Delayed Advancement in the Repair of Lacerated Flexor Profundus Tendons*

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The literature on hand surgery is replete with articles on methods of treatment of lacerated tendons. The principle of delayed repair by tendon graft when both flexor tendons are lacerated in "no man's land" is generally followed [1], although primary repair by graft [3] and by primary suture of both tendons under certain conditions [7,9] are practiced by some. When the profundus tendon is lacerated alone, repair by primary suture [9], by delayed suture [7], or by a thin tendon graft past the intact sublimis [10] are advocated by some, while others prefer tenodesis [11] or arthrodesis [4] of the distal joint in slight flexion.

A fifth method of treatment that has been advocated for use when the profundus tendon is lacerated at or distal to the insertion of the sublimis is advancement of the proximal end of the profundus after removal of its distal portion, when the latter does not exceed a centimeter in length [2,5,6,8]. The purpose of this paper is to demonstrate the advantages of this method of treatment and discuss its indications and limitations as observed in twenty-seven consecutive cases during the past five years.

The primary advantage of advancement is that the suture of the tendon occurs at its insertion thus eliminating all the problems of adhesion, and passage of the tendon through the opening of the sublimis on flexion and extension. Delay of the advancement allows the skin and soft tissues to heal, fractures to stabilize, and the repair of the tendon under ideal elective conditions.

The disadvantages of the procedure are the temporary incomplete extension of the affected finger due to the relative shortness of the repaired tendon and the slight hyperextension of the adjacent fingers that occurs, particularly when the procedure is performed in one of the medial three fingers. This, of course, is due to the incomplete separation of the flexor profundus muscle supplying the long, ring, and little fingers.

Incomplete extension of the involved finger is uniformly noted in the postoperative period. With use of the hand, extension gradually increases; in this series, full extension was achieved by all patients by the sixth month. When the profundus of the long, ring, or little fingers is advanced slight hyperextension of the proximal interphalangeal joints of the adjacent unaffected fingers will be noted during the first few months postoperatively. This is due apparently to the relative lengthening of adjacent profundus tendons which accompanies the advancement of the lacerated profundus. As full extension of the affected finger is realized the hyperextension of the adjacent fingers becomes less apparent but, on careful examination, a very slight residual hyperextension can be demonstrated on full extension in the adjacent, ring, or long finger, as the case may be, in every advancement. The patients are unaware of this finding and it is not disabling.

Delayed advancement has been used in this series only where the laceration of the tendon is at or distal to the insertion of the sublimis. In all patients, this

* Read at the Annual Meeting of the American Society for Surgery of the Hand, New York, N. Y., January 31, 1958.

TABLE I

Total—27 Cases (5 with 2 fingers involved)	
Mean age	— 32 (extremes 17—64)
Flexor pollicis longus	— 4
Profundus, index	— 7
Profundus, long	— 11
Profundus, ring	— 7
Profundus, little	— 3
Results:	
Full flexion	— 23
Full extension	— 32
Incomplete flexion (but reach palm)	— 9
Incomplete extension	— None
Hyperextension in adjacent fingers	— 7

tendon has been intact and functioning normally. With this limitation, the procedure works equally well in all fingers. The problems of hyperextension of adjacent fingers does not occur when the flexor pollicis longus or profundus of the index are advanced, nor are these in turn affected by advancement of the middle, ring, or little finger profundi.

As illustrated in Table I, the maximum delay in this series was seven weeks. Little or no difference in the appearance of the proximal tendon end, its relative length, or the postoperative course could be demonstrated regardless of the length of time that elapsed between the injury and the repair. Apparently maximum shortening occurs in the first three weeks and little change occurs subsequent to that time.

The proximal end of the tendon retracts in its sheath and rounds off without proliferation. Although it becomes slightly bulbous, in none of these patients was there any difficulty in passing the end through the sublimis opening into the distal portion of the finger.

The results with this method of treatment are uniformly good. All patients in this series gained full extension and were able to touch the palm on full flexion. All but eight of the twenty-seven patients were able to reach the distal palmar

FIG. 1-A

FIG. 1-B

FIG. 1-C

A shipyard employee, forty-five years old, suffered a crush wound to the middle phalanges of the long and ring fingers. Flexor profundus tendons were lacerated 1.5 centimeters from the distal joint on the long finger and two centimeters on the ring finger.

Wounds were carefully debrided and closed. Tendon repair by advancement was accomplished five weeks later. Photographs illustrate function six months past injury.

crease with the finger tip, and of these six had, in addition to the tendon laceration, bone or joint injury. The patient illustrated gained full flexion of the long finger but failed to reach the distal palmar crease with the tip of the ring finger by one centimeter.

If the use of the procedure is limited to those patients in whom the laceration is distal to the insertion of the sublimis, the maximum advancement will be about 2.5 centimeters. Usually the laceration occurs with the finger in flexion and the average advancement will be one to two centimeters.

This method of treatment is not advocated for lacerations of both tendons proximal to the proximal interphalangeal joint.

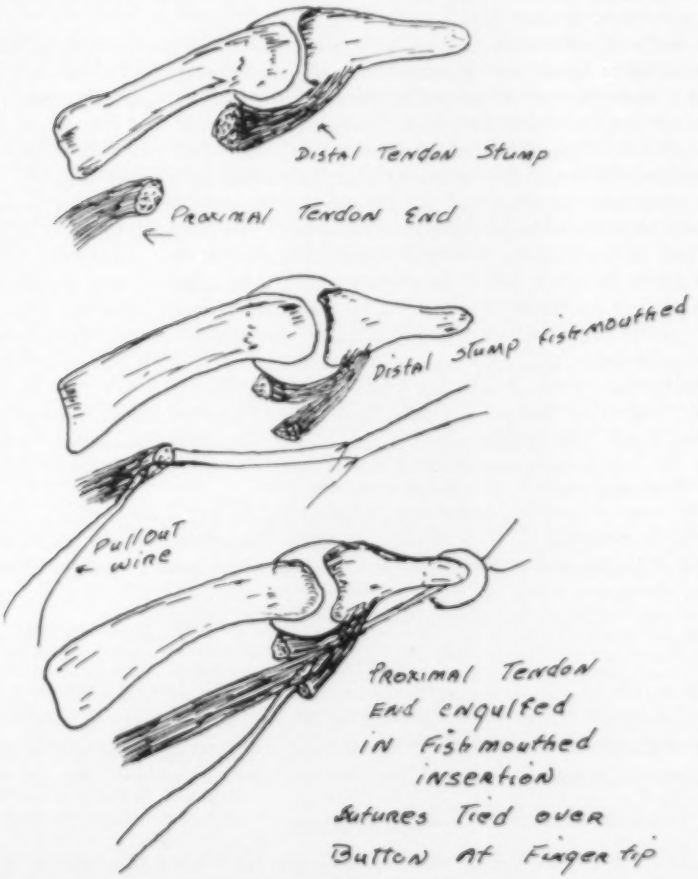
Distal Tendon Stump
Proximal Tendon End
Distal Stump fishmouthed
Pull out wire
Proximal Tendon End enqulfed in Fishmouthed inseration
Sutures Tied over Button at Finger tip

FIG. 2

Technique used in attaching advanced tendon to distal stump.

TECHNIQUE

Upon admission, the wound resulting in the laceration or separation of the profundus tendon is carefully debrided, irrigated, and repaired with fine interrupted sutures. Care is taken to ensure primary healing of the skin and subcutaneous tissue. The tendon is ignored; no attempt is made to suture digital nerves at this time if they also are lacerated. If there has been loss of substance, primary flap grafting is performed using the adjacent finger, the abdomen, or other arm.

If flexion creases are crossed repair by Z-plasty is important to prevent contracture of soft tissues. Associated fractures are reduced and fixed with pins when indicated to ensure reduction and stability.

The finger is then splinted in a position of function and held until healing is complete. This may require two to six weeks. After the soft tissue is healed, a period of exercise, passive motion, and massage is usually necessary to regain pliability of the skin and joints before tendon advancement can be performed. Fractures must be stable and joints must be free before the tendon restoration is accomplished.

The advancement of the tendon is accomplished through a mid-lateral finger incision. Sheath and pulleys are freed laterally and reflected with the skin flap. When the digital nerves have been lacerated they are repaired at this time in the usual manner with fine silk.

Usually the proximal end of the flexor tendon has retracted into the palm necessitating a transverse incision near the distal crease. The tendon end is threaded back through its tunnel and delivered into the finger. The distal end is resected first proximal to the distal interphalangeal joint and fish-mouthed. The proximal end is then advanced into the divided distal end and held in place using stainless-steel wire tied over a button after the method of Bunnell (Fig. 2).

In resecting the distal end of the tendon, care must be taken not to separate the insertion from its volar capsular attachment. The tendon will freely glide over this joint if the tendon is resected just proximal to the joint and then split transversely. This will allow the proximal end to be engulfed and supply considerable surface for union to occur. If the insertion is freed from the volar plate, injury to the volar capsule will result and a subsequent painful flexion contracture may occur.

Following repair, it will be noted that the affected finger will be held in varying degrees of flexion depending upon how much advancement was necessary and how much contracture has occurred during the period of delay. Postoperatively, the hand should be splinted in sufficient flexion of the wrist to allow the finger full extension of the distal two joints.

Subsequent handling follows the same course of any tendon repair. The pull-out wire is removed at three weeks and graduated exercises and other physical therapy initiated in the usual manner. Full flexion is gained rapidly. Full extension of the finger with the wrist in dorsiflexion may require several weeks. In none of our patients has tendon-lengthening been required.

CONCLUSION

Several methods of treatment are available for repair of the flexor profundus tendon lacerated distal to the insertion of the sublimis. Attention is called to the less well known method of repair by delayed advancement. Uniformly good results may be anticipated if certain basic principles are observed.

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Congenital Pseudarthrosis of the Tibia*

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In this paper, recommendations are made regarding the management of congenital pseudarthrosis of the tibia. Fifteen patients, operated on for this condition by members of the Staff of the Campbell Clinic, are reported.

Experience has shown that following an initial successful bone-grafting operation, refracture is common during growth and that, therefore, end-result studies made before skeletal maturity are not reliable. Seven of our fifteen patients have now reached skeletal maturity, and end results can be reported not only regarding treatment but also regarding social and economic status. These seven have previously been reported in 1941[6] and 1948[7]; in 1948 only one had reached skeletal maturity. Eight more patients have been treated since 1948; none of these can be included in an end-result study because none have reached skeletal maturity. They are of interest in regard to pathology and methods of treatment.

CASE REPORTS

Group I: Patients Who Have Now Reached Skeletal Maturity

CASE 1. S. A., a white girl, was first seen at the age of twenty-seven months on July 6, 1925. Anterior bowing of the tibia had been noted since early infancy, and she had sustained a fracture of the right tibia at the age of fifteen months following a minor fall. Non-union had persisted in spite of treatment in a cast for one month and in a brace for six months. On admission, a mobile pseudarthrosis of both the tibia and fibula was present. It was thought that the fracture had occurred through a pre-existing bone cyst.

On July 10, 1925, a massive onlay homologous graft from her mother's tibia was applied and was maintained by five wire loops; cancellous bone was packed about the site. Postoperatively the extremity was immobilized in a toe-to-groin cast for ten months. The wire loops were removed twelve months postoperatively; roentgenograms made fourteen months after operation showed solid union of the graft and reformation of the medullary canal.

A residual valgus deformity of the ankle was treated by supramalleolar osteotomy at the age of fifteen years, twelve and one-half years after onlay grafting. This healed readily with cast immobilization. Due to a congenital pseudarthrosis of the fibula alone in the opposite leg, with a valgus deformity of the ankle, a supramalleolar osteotomy was done on the left, at the age of fifteen and one-half years. This united without difficulty.

In 1949, she had a painful neurofibromatous mass removed from the left foot. Numerous *café-au-lait* spots were present on the body.

She was last seen February 13, 1958, at thirty-five years of age, thirty-two and one-half years following onlay grafting (Figs. 1-A, 1-B, and 1-C). At that time she had no complaints referable to the lower extremities. Both tibiae were of equal length, but both ankles remained in approximately 20 degrees valgus deformity. She was a graduate nurse, had married, had a child, and was a social and economic success.

Tissue removed at the time of her initial operative procedure was not studied microscopically. Tissue removed from the sole of the left foot was diagnosed as neurofibroma.

CASE 2. H. L., a white boy, two and one-half years old, was first seen at the Campbell Clinic on May 25, 1937 (Fig. 2-A). Deformity, with motion in the tibia, had been noted at birth; and many *café-au-lait* spots were present on the body. There was tapering of the bone ends of the tibia and fibula when the child was first seen at the Clinic; one operation for the correction of the deformity had been done at the age of nine months. At the age of two years and seven months, a lengthening of the tendo achillis and a Hallock operation [20], with iliac chips from the mother being used, were done. A year later these grafts had resorbed and clinical motion was present at the site of the pseudarthrosis.

* Read in part at the Joint Meeting of the Orthopaedic Associations of the English-Speaking World, Washington, D. C., May 12, 1958.

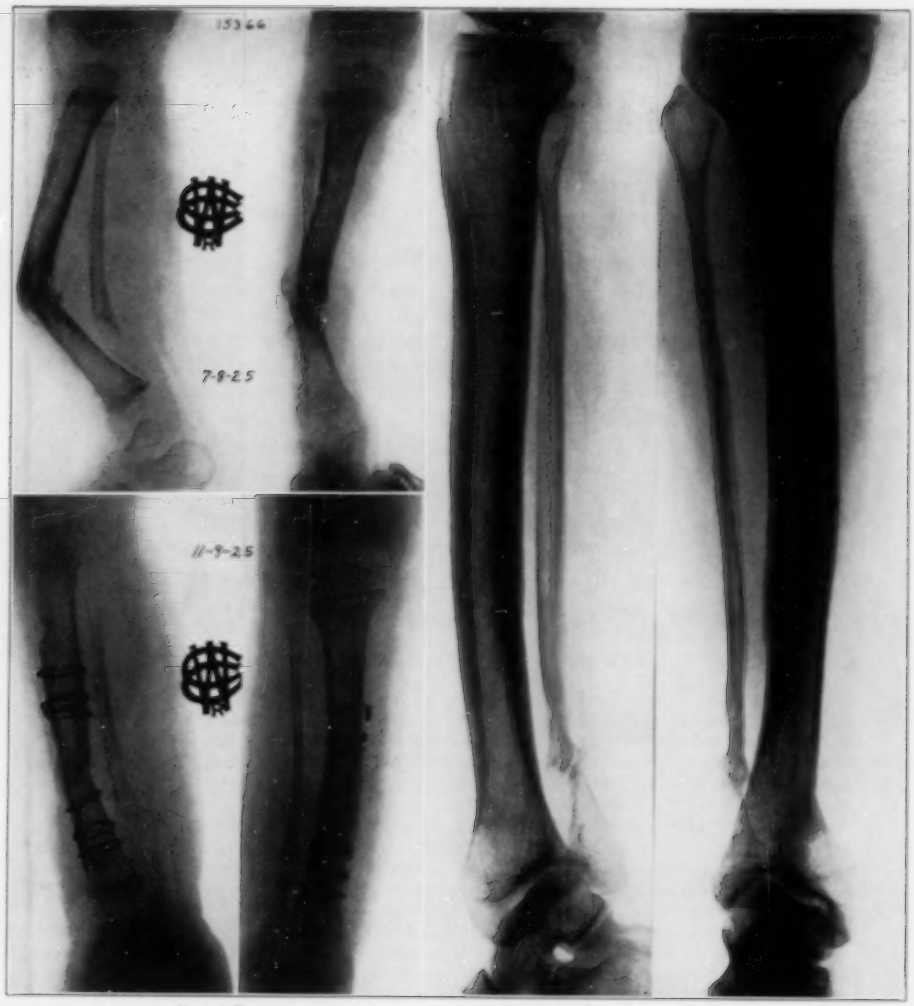

FIG. 1-B FIG. 1-C

Fig. 1-A: Case 1. Original pseudarthrosis (top left).
Fig. 1-B: Four months after massive onlay bone graft.
Fig. 1-C: Thirty-two and one-half years after onlay bone graft.

On March 2, 1939, massive single onlay grafting was done, tibial bone from the mother being used. The graft was held in position by four Vitallium screws. Postoperatively the extremity was immobilized in a toe-to-groin cast for five months; a heel-to-groin brace was used for a year (Fig. 2-B). Fourteen months after operation the screws were removed. He continued to use a heel-to-groin brace for another two years (Fig. 2-C). The brace was then discarded against advice.

Three years and seven months following the onlay grafting, the child fell from a merry-go-round and sustained a fracture of the tibia and fibula at the site of previous pseudarthrosis. Non-union persisted in spite of immobilization in a cast for two and one-half months; the bone ends showed progressive absorption.

On June 4, 1945, at the age of ten and one-half, dual onlay grafting was done, the opposite tibia being used as the donor bone. Internal fixation was obtained by four screws. Use of a cast was continued for one year, and a heel-to-groin brace for four years.

Roentgenograms, made seven and one-half months following the dual onlay grafting, showed solid union (Fig. 2-D), and roentgenograms, made thirty-six months after operation, showed a well established medullary canal. He was last seen at the age of twenty-three years, twelve and one-half years after the last operative procedure (Fig. 2-E). There was three-quarters of an inch shortening of the right tibia with only one-quarter of an inch over-all shortening of the entire

FIG. 2-A

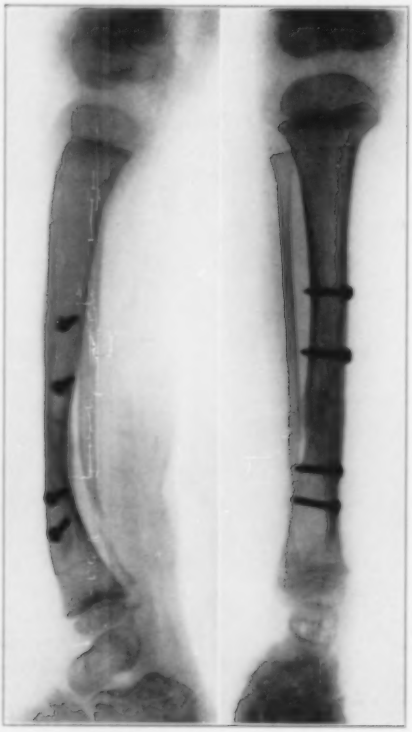

FIG. 2-B

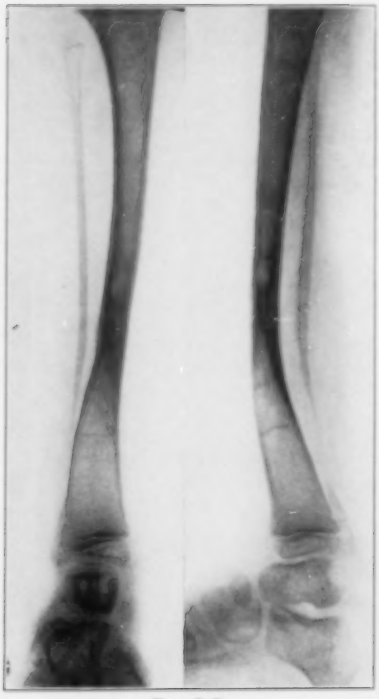

FIG. 2-C

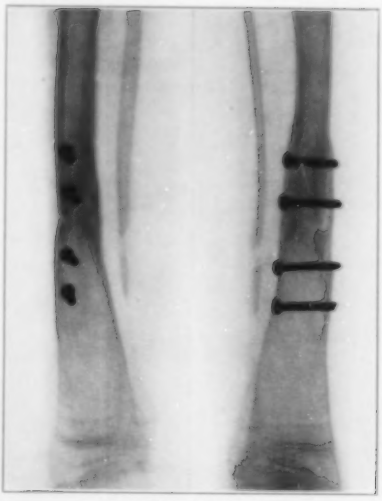

FIG. 2-D

Fig. 2-A: Case 2. Original pseudarthrosis.

Fig. 2-B: Eight months after massive onlay bone-grafting.

Fig. 2-C: Three years after massive onlay bone-grafting. There is union but also constriction of the bone and narrowing of the medullary canal. A reinforcing bone graft should have been applied at this time.

Fig. 2-D: Seven and one-half months after dual onlay graft: solid union.

extremity. On the anterior projection, a 5-degree valgus deformity of the tibia and a 15-degree valgus tilt of the right ankle were noted; on the lateral projection a 10-degree anterior angulation of the tibia was seen. The patient had no complaints relative to the leg but did have multiple neurofibromatous nodules over the body and a severe thoracolumbar kyphoscoliosis.

He had been economically productive in a gainful occupation only a few months before being convicted of a misdemeanor and imprisoned. When last seen, he was undergoing psychiatric investigation. From a social and economic aspect, this should have been classed a successful case.

Microscopic Examination

The tissue removed from the site of pseudarthrosis at the time of single onlay grafting showed large masses of heavy, sclerotic bone and hyaline cartilage embedded in dense but cellular connective tissue. There was active osteoblastic and osteoclastic activity and areas of chondroid change away from the main site of activity. No neurogenic elements were seen. There was considerable thickening of the walls of the muscle arteries.

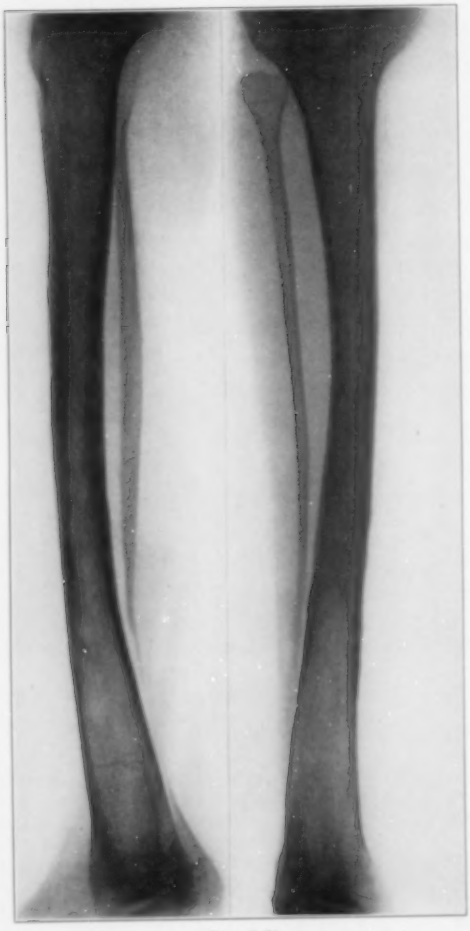

FIG. 2-E

Twelve and one-half years after dual onlay graft.

In the periosteum there was cellular fibrous tissue resembling fascia and quite similar to that in which the pseudarthrotic joint was embedded. Occasional small nerve trunks were seen; they did not appear abnormal. Again, some of the muscular arteries had thickened walls.

Tissue removed at the time of the dual onlay grafting showed two masses of dense, newly formed bone which came to rather blunt points in cellular fibrous tissue, like that described above,

intervening between these two fragments. This connective tissue was osteogenic. No neurogenic elements were seen. It was fairly vascular, but no large arteries were present.

No tissue was available from the first two operative procedures.

CASE 3. W. J. W., a five-year-old white girl, was first seen on July 19, 1939, with a history of an ununited fracture of the left tibia since birth. A fibular graft from the opposite leg had been applied at the age of one year followed by cast immobilization for three years, but non-union had persisted clinically and roentgenographically. There was three-eighths of an inch shortening on the affected side.

Three days later, on July 22, 1939, at the age of five years, dual onlay grafting was done in which tibial bone from the father was used. Five months later, the screws were removed. Roentgenograms made at this time showed union of the graft, but a medullary canal was not established until two years and seven months postoperatively, at approximately the age of eight.

When last seen on October 10, 1942, the affected leg was three-eighths of an inch longer than the normal one. Considerable anterior bowing of the tibia persisted, and the bone was thin and fragile. We then considered her operation a failure, for at that time, although the tibia had united and had re-established its medullary canal, we felt that due to the bowing and the thinness of the tibia she was certain to have further difficulties with it, probably in the form of a fatigue fracture.

In the latter part of 1942, she was lost to follow-up, but in the present survey we found that she had been admitted to the James Lawrence Kernan Hospital in Maryland on January 10, 1944. Because of recurrence of *pseudarthrosis* of the tibia and fibula and persistence of this condition following ten weeks of cast immobilization, a second dual onlay bone graft was applied with bone chips packed about the area. Her postoperative condition was complicated by a slough of skin on the medial aspect of the leg. Later a sliding full thickness skin graft was done, but this again was complicated by skin slough. Several pieces of bone sequestrated through the wound; the wound edges then gradually healed. Cast immobilization was maintained until September 10, 1945, and then a brace was applied. At this time the tibia had united but brace immobilization was advised.

At our request, she was again seen at the Kernan Hospital in March 1958. In the interim, the patient had continued to wear a brace, had graduated from high school and business college, and had worked as a stenographer until she married. She stated she had been able to lead a normal life with very few exceptions, such as dancing. She was the mother of a nine-month-old child, and was a social and economic success.

Microscopic Examination

Bone removed at the time of the initial onlay grafting showed large dense masses of newly formed sclerotic bone which had a Paget-like pattern reflecting an irregular flow of bone formation and destruction. This ended abruptly in fibrocartilage and fibrohyaline cartilage. At one extremity of fibrocartilage, there was a well developed subchondral bone plate, and enchondral ossification appeared to be occurring beneath this. The bone was quite vascular, the vessels being large, dilated, and fairly thin-walled. No neurogenic elements were seen.

CASE 4. R. L. D., a three-year-old white boy, was first seen March 25, 1935. His leg had apparently been normal at birth, but following weight-bearing there developed a gradual antero-lateral bowing of the left leg.

Four days prior to admission, the child had turned his ankle and had had immediate pain in the leg. Roentgenograms revealed a fracture at the junction of the middle and lower thirds of the tibia through a cyst; a large cyst was also seen in the upper third of the tibia but there was no fracture at this level.

For the next four years the leg was protected by braces or by plaster immobilization but it failed to unite. On September 23, 1939, at the age of seven and one-half, dual onlay bone-grafting, with tibial bone from the mother, was accomplished. Roentgenograms made four months later showed beginning union. The leg was immobilized in a cast for six months and in a brace for two years. The five screws which had been used for internal fixation were removed ten months after operation, and roentgenograms made eleven months postoperatively showed union well established, the fracture line obliterated, and a good medullary canal; the cyst in the upper third of the tibia had almost completely disappeared without treatment.

On January 22, 1947, the boy, at the age of fifteen, seven years and four months postoperatively, was fully active without a brace. The affected leg was three-quarters inch longer than the opposite one, and a calcaneovalgus deformity of the foot was present. *Café-au-lait* spots were present on the abdomen and buttocks. Roentgenograms showed a sound tibia with mild antero-medial bowing.

No further personal follow-up or roentgenograms have been obtained, but a report from the patient's father in January 1958 stated that at age twenty-six, eighteen years and three months postoperatively, the young man was doing sea duty with the merchant marine with no limp and no disability in his leg. Socially and economically, then, we consider the result successful.

Microscopic Examination

The tissue removed at the time of curettage and dual onlay grafting showed the bone, both

proximally and distally, to be dense and heavy. There was a very active osteoblastic process. The ends of the two segments ended abruptly with only small, blunted spicules extending into a zone of cellular fibrous tissue which showed some cartilaginous metaplasia and an occasional small cyst. In a few points, the cartilage united the bony trabeculae, and here and there was seen to be minimal osseous union. Good callus was present on one cortical aspect of the lesion, but there was amorphous material reflecting a degenerative change in this callus between the segments of the cortex. No neurogenic elements were seen.

Case 5. J. E., a five-year-old white boy, was first seen at the Campbell Clinic in September 1941. From his foster parents, it was learned that the child had struck his left leg against a table and presumably sustained a fracture at thirteen months of age; however, they thought that this leg had been crooked prior to the fracture. His leg had been immobilized in a cast for eight months and in a brace for three years. Roentgenograms at the time he was seen at the Campbell Clinic showed a typical pseudarthrosis at the junction of the middle and distal thirds of the left tibia, with tapering of the bone ends and overriding of the fragments. *Café-au-lait* spots were noted on his body. On September 15, 1941, at age five years, a dual onlay bone-grafting was done, tibial bone from the foster father and internal fixation by four Vitallium screws being used. Postoperatively, cast immobilization was continued for five and one-half months, and then a brace was applied. Two and one-half months postoperatively, his leg was clinically solid, and weight-bearing, in a brace, was allowed approximately six months after operation. Roentgenograms, made at this time, showed obliteration of the fracture line and union of the graft to both tibial fragments. Two months later, eight months postoperatively, the screws were removed, and roentgenograms showed complete union of the dual graft and obliteration of the fracture line; but moderate anterior angulation was present.

Roentgenograms, made two years and eleven months after operation, showed a fairly well developed medullary canal, but anterior bowing and valgus deformity of the ankle which had been present postoperatively had increased. The affected lower extremity was three-quarters of an inch shorter than the opposite one; however, the femur on the affected side was longer.

Periodic roentgenograms, beginning at three years and four months after operation, showed the progressive development of a fatigue fracture without callus formation and associated with sclerosis of the bone about the site of former pseudarthrosis. There was noted to be gradual narrowing of the medullary canal. A complete fracture occurred August 14, 1946, five years postoperatively, when the patient, wearing a brace, slipped while going down steps.

A below-the-knee amputation was performed on September 2, 1946, at approximately age ten. At this time the affected tibia was one and one-half inches shorter than the normal one, and roentgenograms showed marked absorption of bone about the fracture site.

After the below-the-knee amputation, the patient was very quick to adjust to his prosthesis, and when last heard from in January 1958 was carrying out practically all the normal activities of any young man of twenty-one years.

Although this patient from a reconstructive standpoint is considered a failure, both the patient and his foster father are fully convinced that below-the-knee amputation was the procedure of choice following refracture, in view of the possibility of repeated surgical attempts to gain union with the outcome in doubt, and the ultimate outcome as to the usefulness of the leg likewise in doubt.

Microscopic Examination

The tissue removed at the first operative procedure showed the presence of an adventitial bursa between the skin and the bone ends. The bone consisted of segments of somewhat sclerotic irregular bone embedded in dense, very cellular fibrous connective tissue. The tissue seemed to be undergoing metaplasia to cartilage or cartilage-like material in a few areas. At one point, the bone resembled the bone that would be seen in a subchondral bone plate. No neurogenic tissue was seen.

The amputated lower leg included the site of pseudarthrosis. The bone was very dense and sclerotic. There was small callus on one surface. The marrow spaces were filled with a cellular fibrous tissue which became more cellular and had a distinct whorled appearance as the site of the non-union was approached. Distal to this, in either direction, osteoblastic activity was pronounced, but near the site of the pseudarthrosis, the bone trabeculae ended rather abruptly in very cellular fibrous tissue which contained amorphous debris. Near this, osteoclastic activity was so pronounced that it was noted to be the most striking feature of the specimen. The osteoclasts were arranged in palisade formation in many areas and far outnumbered the osteoblasts. The picture was reminiscent of what one might see in hyperparathyroidism. It was noted that the stroma here might erroneously be interpreted as neurofibroma.

Case 6. R. K., a white boy, seven and one-half years old, was first seen at the Campbell Clinic on March 2, 1943. Anterior bowing of the right leg had been noted at birth, and roentgenograms made shortly after birth showed increased tibial and fibular bowing. The tibia was solid and the diameter of the bones remained normal. Roentgenograms made six months later showed a completely fractured fibula with absorption of the fragments, and a decrease in the diameter of the medullary canal of the tibia with increasing sclerosis. Casts were used intermittently for immobili-

zation from age eight months to age two years. A corrective osteotomy of the tibia was done. This resulted in non-union.

At the age of four and one-half years, inlay grafting had been done, bone from the opposite tibia being used. Non-union persisted, and the leg had been supported in a brace until the time of his admission to the Campbell Clinic. At that time he had a typical mobile pseudarthrosis of the tibia and fibula with a two and one-half inch shortening of the affected leg. Many *café-au-lait* spots were noted over the body, and one tumor which was thought to be neurofibroma was present on the sole of the left foot. On March 3, 1943, a dual onlay bone graft was applied, bone from the mother's tibia being used. Internal fixation was obtained with four Vitallium screws. Cast immobilization was maintained for three months and a brace was worn for three and one-half months. At this time, although the fractures had solidly united, he sustained a fracture while walking in a heel-to-groin brace at the level of the proximal screw in the distal fragment. The limb was immobilized in a cast for another three months. On January 4, 1944, at the age of eight, dual onlay grafting with bone from the father's tibia was done. At the time of the operation a fracture occurred through osteoporotic bone just above the level of the ankle at the lower end of the graft. Immobilization in a toe-to-groin cast was maintained. Roentgenograms made ten months postoperatively showed union of the graft with both tibial fragments, with complete obliteration of the fracture line; the supramalleolar fracture had likewise united, but with anterior angulation. The patient was last seen at the Campbell Clinic in October 1944 and was subsequently followed by Dr. Leo Mayer, from whom later study was obtained.

The patient continued to wear a brace from 1944 until 1952. In June 1952 he sustained a fracture at the site of angulation of the distal portion of the tibia. This was first treated by immobilization in a plaster cast for one month. Later an ankle fusion was performed, and a medullary rod was inserted through the ankle up across the site of pseudarthrosis. Absorption of bone in the region of the fracture again occurred, and in July 1953 multiple cortical and cancellous iliac grafts were placed in a gutter at the site of pseudarthrosis and in both fragments. Immobilization was obtained by a toe-to-groin cast. In December 1953, five months postoperatively, roentgenograms and clinical examination revealed solid union of the leg. The medullary nail was left in place.

When last seen on February 3, 1958, the patient walked with a mild limp. He had two and three-quarter inches shortening of the right leg. However, the ankle had been fused in equinus position, so that with a two and one-half inch elevation of the heel alone inside his shoe, the pelvis was kept level. The leg was smaller in diameter than the opposite one, and the skin was considerably scarred, but the patient had graduated from college and was employed as an accountant, in which occupation he traveled about the sidewalks and subways of New York City each day. His physical limitations were primarily confined to inability to participate in athletics. He was last seen, at the age of twenty-one, fourteen years after the second dual onlay graft and four and one-half years after the application of multiple chip grafts about the fracture site supplemented with the previously indwelling medullary nail. The nail was still in place and causing no disability, being embedded in the soft tissue beneath the calcaneus.

Microscopic Examination

The soft tissue removed from the site of pseudarthrosis at the time of initial dual onlay grafting revealed a cellular fibrous tissue containing a moderate number of vessels which did not seem to be abnormal. The tissue was seen to be undergoing mucinous change in some areas; no neurogenic elements were seen.

The tissue removed at the time of the second dual onlay grafting showed a large mass of dense sclerotic bone which was in a quiescent phase. The soft tissue was extremely cellular, and a foreign-body reaction was noted with hemorrhage. The most striking feature was a marked hypercellularity of fascia-like connective tissue which blended into adjacent fat, with septa coursing into the fat. This was said to resemble the fibrocytic proliferation seen in a Dupuytren's lesion or fascial fibroma. There was no evidence of abnormality of nerve tissue; very few nerve fibers were present.

Sections removed at the time of the last operation, in 1953, showed osseous tissue which was non-viable. There was scar formation in the marrow spaces. On the periphery of the non-viable bone, some areas of callus formation were noted.

CASE 7. V. L. S., an eight-year-old white girl, was first seen at Campbell Clinic on February 2, 1944 (Fig. 3-A). A deformity of her right leg had been noted since she began walking at the age of nine months. Since that time she had been treated intermittently by cast and braces. There was clinical evidence of a mobile pseudarthrosis of the tibia and fibula, with marked valgus deformity of the lower third of the leg; a questionable *café-au-lait* spot was present on the chest.

At the age of eight, on February 8, 1944, dual onlay bone-grafting was done, bone from her father's tibia being used. Seven months later, the grafts had united with the fragments of the tibia but the fracture line was still present. Cast immobilization was maintained continuously for twenty and one-half months, during which time the dual onlay graft was gradually absorbed and the deformity recurred (Fig. 3-B). On November 26, 1945, a second dual onlay graft was applied, bone from the opposite tibia being used. The patient was discharged wearing a cast on June 1, 1946, and has subsequently been followed elsewhere (Fig. 3-C). The screws through the proximal fragment were removed three and one-half years after the second dual onlay grafting; immobiliza-

FIG. 3-A FIG. 3-B FIG. 3-C FIG. 3-D

tion was maintained by means of a cast for one year, and a brace was worn continuously for a total of twelve years and three months. The medullary canal was re-established three months postoperatively; the grafts showed union nine months postoperatively. However, the bone was narrow and angulated in the lower third of the tibia.

The patient was last examined elsewhere at our request on January 29, 1958 (Fig. 3-D). At that time she wore a leg brace with free motion at the ankle. She discarded the brace in the evening when walking about the house for as long as an hour without pain. She had no complaints referable to the knee, leg, ankle, or foot, and was able to walk five or six blocks without tiring. For the previous one and one-half years, she had worked a forty-hour week as a secretary. She had a functional range of motion in her ankle but moderate varus deformity of the heel and mild adduction of the fore part of the foot. The right lower extremity was one and three-quarter inches shorter than the left.

Roentgenograms showed that the tibia was angulated anteriorly and narrow at the site of the previous pseudarthrosis with two small defects which had not completely ossified. Three screws remained in the affected tibia.

The patient had married and could be considered a social and economic success.

Microscopic Examination

The tissue removed at the first operation showed dense sclerotic bone; and, although osteoid seams were present giving a malacic appearance, very little osteoblastic activity was seen. The dense bone ended rather abruptly in a fibrous and fibrohyaline cartilage-like material. Distal to this, there was moderately cellular fibrous connective tissue containing a few vessels and showing some mucinous change. No neurogenic elements were seen.

Comment on Group I

All seven of these patients have reached skeletal maturity. All seven had repeated reconstructive operations. From the surgeon's point of view, one (Case 5) failed because it resulted in below-the-knee amputation; three were moderately successful, two of these (Cases 3 and 7) needing braces, and one (Case 6) needing a shoe elevation; and three were successful (Cases 1, 2, and 4). From a social and economic point of view, all were successful except one (Case 2), and this surgically was a success. The one surgical failure (Case 5) was a social and economic success.

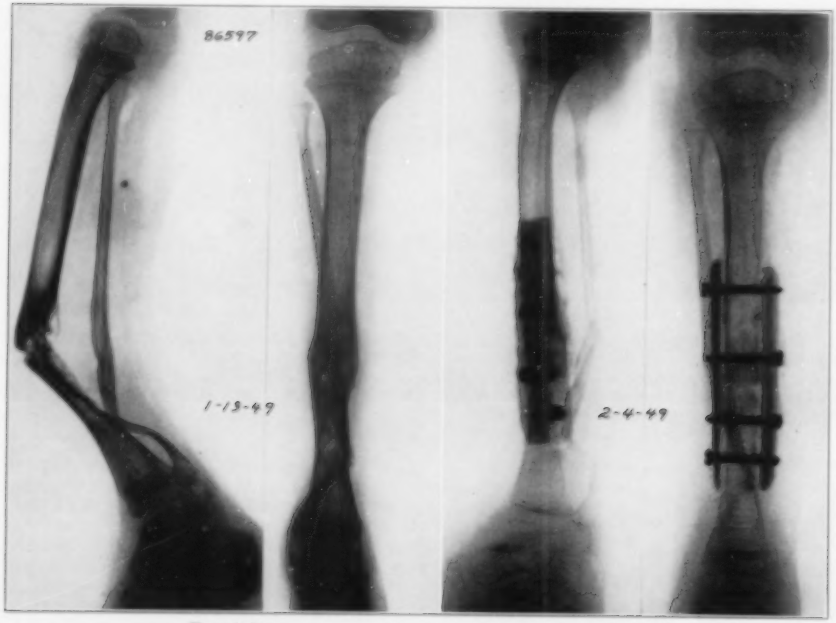

FIG. 4-A FIG. 4-B

Fig. 4-A: Case 8. Original pseudarthrosis.
Fig. 4-B: Two weeks after the first dual onlay graft.

Group II: Patients Who Have Not Reached Skeletal Maturity

CASE 8. E. V., a four-year-old white girl, was first seen at the Campbell Clinic January 13, 1949 (Fig. 4-A). Prior to this time she had had two operations. At the age of two she had tripped and bruised her leg, and a small tumor had developed on the lateral side, the histopathological description of which was unobtainable. The tumor was removed, and the leg was immobilized in plaster for three months. When the plaster was removed, the child fell or was struck, and the tibia was fractured. After closed reduction, the leg was immobilized in plaster for two months. Non-union occurred which was not painful; there was, however, considerable deformity and anterior angulation. A second procedure, the nature of which was not known by the patient, was performed, but non-union persisted[6].

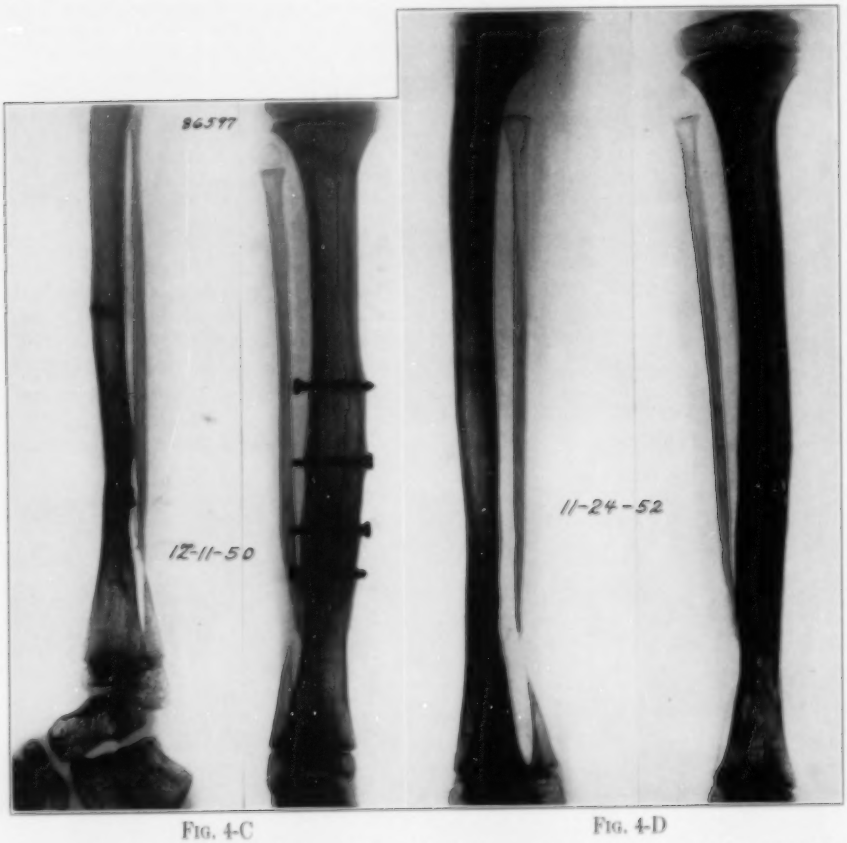

FIG. 4-C FIG. 4-D

Fig. 4-C: Twenty-three months after the first dual onlay graft, showing union of the grafts with the tibia.

Fig. 4-D: Forty-six months after the first dual onlay graft. The medullary canal has been re-established, but there is constriction of bone at the site of previous pseudarthrosis. A reinforcing graft should have been applied at this time.

On January 14, 1949, at the age of four, a dual onlay graft was applied, bone from her mother's tibia being used (Fig. 4-B). Cast immobilization was maintained for six months. A brace was used for five and one-half years. The grafts united (Fig. 4-C), and the medullary canal re-formed (Fig. 4-D).

Approximately four and one-half years after the dual onlay grafting, she was struck by another child, and although in a brace she sustained a fracture at the site of the original pseudarthrosis (Fig. 4-E). On July 1, 1955, at the age of ten, a second dual onlay graft was applied, bone-bank tibial bone and five screws being used (Fig. 4-F). She was maintained in a cast for five months and in a brace for twenty-five months—until the time of writing. Union of the grafts with the tibia had been seen roentgenographically at four and one-half months, and reestablishment of the medullary canal at thirty months postoperatively.

The child was last seen at the Campbell Clinic in January 1958. At this time the five screws were removed under general anaesthesia, and reinforcing homogenous rib grafts were placed about the tibia (Fig. 4-G). A thorough examination failed to reveal the presence of *café-au-lait* spots or other stigmata of neurofibromatosis. At the time of writing she was twelve years old and had not reached skeletal maturity. She will continue to wear a brace until she does.

Microscopic Examination

The tissue removed at the first dual onlay grafting showed a complex pathological picture. Large areas of dense sclerotic bone were either surrounding or being encroached upon by fairly well defined masses of highly cellular connective tissue which was actively osteogenic and in which

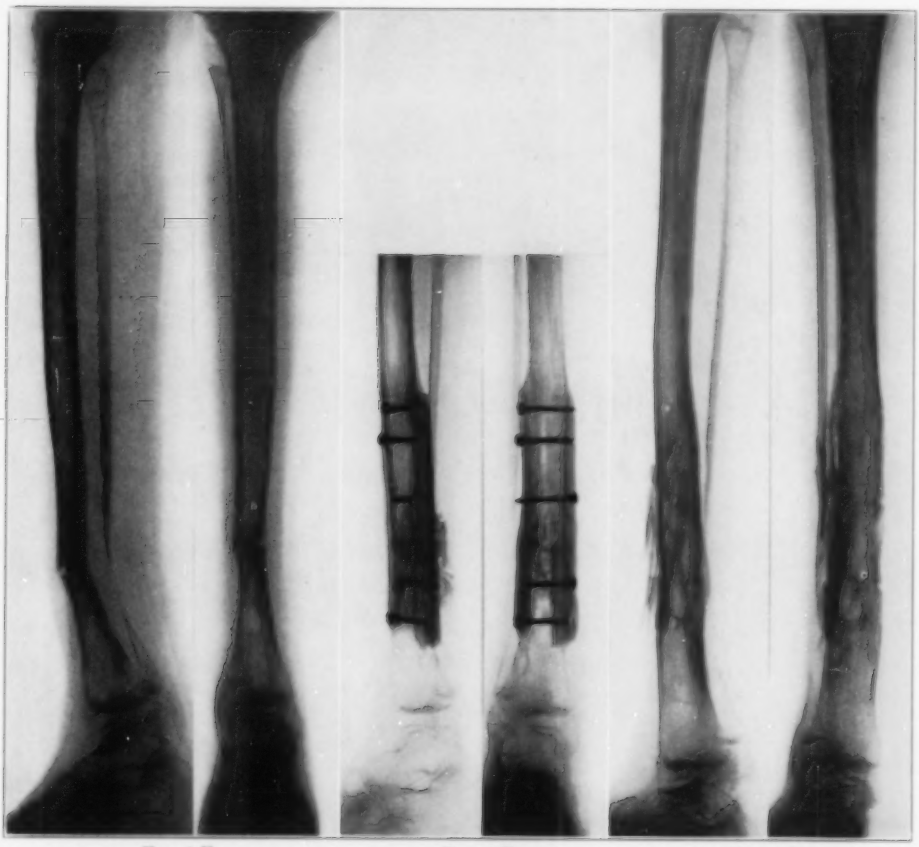

FIG. 4-E FIG. 4-F FIG. 4-G

Fig. 4-E: Refracture upon minor trauma.
Fig. 4-F: Six months following second dual onlay graft.
Fig. 4-G: Union two and one-half years after the second dual onlay graft. One month before this roentgenogram was made, the screws were removed and reinforcing grafts placed about the site of previous pseudarthrosis.

there was a pattern of bone formation reminiscent of fibrous dysplasia. Areas of this connective tissue appeared to be old and showed hyalinization. Between the ends of the bone at the site of pseudarthrosis, there was a definite line of this tissue separating the two fragments, and both active osteoclastic and osteoblastic processes were present. Sections of the periosteum showed a cellular osteogenic connective tissue which resembled that seen in fibrous dysplasia.

In the tissue removed at the second dual onlay grafting, dense, heavy, bone trabeculae were seen with some hyaline cartilage in apposition. Dense, rather hyalinized connective tissue was also seen, containing thick-walled vessels and some large nerve trunks which were densely enmeshed in this tissue. These nerves were in an abnormal location or had been encased in the dense scar tissue.

CASE 9. C. F., a three-month-old white girl, was first seen at the Campbell Clinic on March

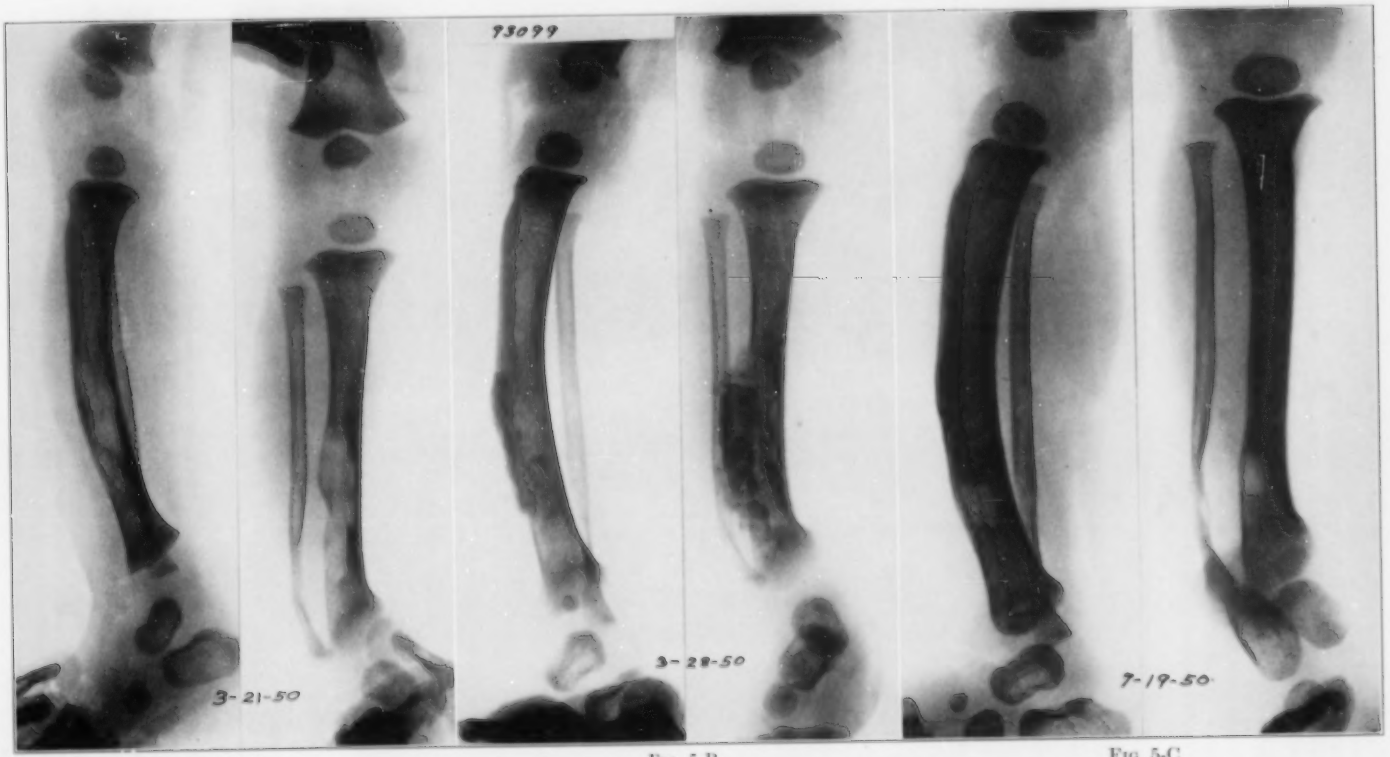

FIG. 5-A FIG. 5-B FIG 5-C

Fig. 5-A: Case 9. Original cystic lesion of the angulated tibia. The fibula is intact.
Fig. 5-B: After curettage of the cyst and filling of the defect with iliac bone from the mother.
Fig. 5-C: Four months later. The cystic lesion partially persists.

FIG. 5-D

FIG. 5-E

FIG. 5-F

Fig. 5-D: Nineteen months postoperatively: the cystic lesion has healed completely; the fibula is still intact.

Fig. 5-E: Three years after curettage and graft. The roentgenogram shows no evidence of recurrence of the cystic lesion but pseudarthrosis is developing in the fibula.

Fig. 5-F: Approximately eight years after curettage and graft. A small cystic lesion is developing in the tibia, and a complete pseudarthrosis of the fibula has occurred.

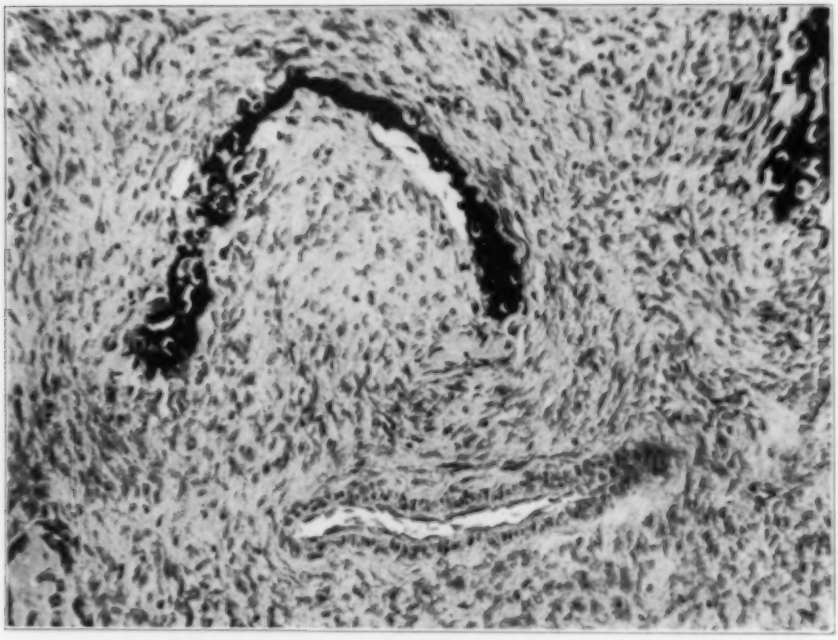

FIG. 5-G

Photomicrograph of material curetted from a cystic lesion at the site of pseudarthrosis. A large, heavily calcified, V-shaped trabecula of metaplastic bone is the dominant feature here. The stroma is cellular, the cells are plump, oval, and spindle-shaped, and a mass of osteoid is present in the upper right corner. This picture is indistinguishable from that of fibrous dysplasia.

27, 1950. A mass was noted on her leg in which there was bowing, and roentgenograms revealed a rather extensive cystic lesion involving the middle and lower thirds of the right tibia (Fig. 5-A). On March 28, 1950, the cyst was curetted and the defect packed with slivers and chips from her mother's ilium (Fig. 5-B). Postoperatively immobilization was maintained by means of a toe-to-groin cast for three and one-half months until roentgenograms revealed almost complete obliteration of the previously grafted cystic area. At that time, an osteoporotic area was seen just below the graft; this was interpreted as persistence of the cyst (Fig. 5-C). She was followed at six-week intervals until nine months postoperatively, at which time roentgenograms revealed that the cystic area in the lower third of the tibia was practically obliterated and the medullary canal had been reestablished. In view of persistent angulation of the tibia, a bow-leg splint was applied for night use and a bow-leg brace was worn for day use. She was then seen at intervals of three months, six months (Fig. 5-D), and twelve months (Fig. 5-E), with no evidence of recurrence of the cystic area until January 25, 1958. The brace had been discontinued after approximately one and one-half years. At her last visit the patient was normally active for a child of eight years. There was no shortening of either lower extremity, and no evident deformity. In roentgenograms made at this time, the tibia appeared essentially normal, with mild anterior bowing in the middle, but a small cystic lesion had developed in the anterior cortex at the site of the lower level of the previous cystic lesion, and a frank pseudarthrosis of the fibula had occurred (Fig. 5-F). A thorough examination of the child failed to reveal any *café-au-lait* spots or other stigmata of neurofibromatosis.

This child will be followed at regular intervals, and if the cystic lesion shows evidence of increasing in size or of failure to disappear, it will be prophylactically curetted and packed with cancellous bone.

Microscopic Examination

The tissue removed March 28, 1950, was very cellular and fibrous, containing spicules of metaplastic bone. The picture was at least highly reminiscent of, and probably indistinguishable from, fibrous dysplasia.

CASE 10. J. B. W., a nine-month-old white girl, was first seen at the Campbell Clinic November 3, 1953, with a history of a deformed left leg since birth. At age six months, a diagnosis had been made of congenital pseudarthrosis with no initiating trauma. Initial roentgenograms showed a

fixed pseudarthrosis with a cystic lesion in the tibia. No *café-au-lait* spots or other congenital anomalies were seen. The extremity had been immobilized in a toe-to-groin cast for three months. On November 4, 1953, dual onlay grafting of the left tibia, with bone from her mother's tibia, was done. Postoperatively immobilization was maintained in a toe-to-groin cast for four months. Roentgenograms at that time showed absorption of the graft about the distal fragment.

On March 3, 1954, a second dual onlay bone graft was applied, bone-bank cortical bone supplemented with autogenous fibular bone being used. Immobilization was maintained by a toe-to-groin cast for three and one-half months, and a heel-to-groin brace was worn for twenty months. Follow-up roentgenograms showed gradual absorption of the graft. On March 8, 1956, at the age of three years and three months, a third dual onlay graft was applied, bone-bank tibial bone being used. Immobilization was maintained by a toe-to-groin cast postoperatively for fourteen months; a heel-to-groin brace was worn for four months. At this time, she sustained a fatigue fracture below the graft through an osteoporotic defect. When the patient was last seen in January 1958, the extremity was again immobilized in a toe-to-groin cast; the new fracture showed no tendency toward union. Open reduction with reapplication of a bone graft and placement of a medullary nail in the tibia is now contemplated.

Microscopic Examination

The tissue removed at the first operation showed a thickened periosteum which was extremely cellular due to a hyperplastic process consisting in proliferation of fibroblastic cells which in some places were irregularly arranged and in others had a distinct whorled arrangement. Irregular areas were vascular. The periosteum showed a hyperplastic process which was said to be closely analogous to that seen in fascial fibromatosis. The bone removed was dense and sclerotic. At the end of each fragment, there was a large mass of hyaline cartilage which was covered by periosteum or perichondrium. Active bone formation was present.

The periosteum removed at the second operation resembled that removed initially; it showed cellularity which was due to hyperplasia, a proliferation of fibroblastic cells which blended into the less cellular adjacent fascia-like tissue. The tissue in one area had an obviously osteogenic potentiality, since small trabeculae of bone had been produced. A few nerve fibers were isolated in the connective tissue and showed what was interpreted as a degenerative change.

The tissue removed at the third operation showed again marked cellularity and proliferation again blending gradually into adjacent less cellular connective tissue or fascia-like tissue. Again it was noted that this was not a tumor but did resemble fibromatosis. In areas, there was seen to be early mucinous change and also cartilaginous metaplasia. A space lined with what looked like synovial tissue with a villonodular appearance was also seen.

Case 11. D. B. B., a seven-month-old white boy, was first seen at the Campbell Clinic July 6, 1956, with a noticeable deformity in the left lower extremity; this had been present from the second day of life, when the child had been seen by a physician and a diagnosis made of congenital pseudarthrosis of the tibia. On examination at Campbell Clinic there was a fixed pseudarthrosis at the junction of the middle and distal thirds of the left tibia (Fig. 6-A), with no evidence of *café-au-lait* spots or other stigmata of neurofibromatosis. On July 11, 1956, dual onlay grafting was accomplished, bone from his mother's tibia being used (Fig. 6-B). Immobilization was maintained postoperatively by a toe-to-groin cast. During cast immobilization there was absorption at the site of pseudarthrosis and progressive recurrence of the anterior angulation (Fig. 6-C).

On February 8, 1957 (Fig. 6-D), a triangular medullary nail was inserted retrograde at the distal fragment down anterior to the ankle joint and calcaneus and thence up through the proximal fragment for stabilization. An autogenous fibular graft with tibial shavings was then placed about the tibia. Again immobilization was achieved postoperatively by means of a toe-to-groin cast.

When next seen on February 5, 1958 (Fig. 6-E), roentgenograms showed union of the pseudarthrosis with such growth of the distal fragment in length that the distal end of the medullary nail which had initially extended into the sole of the foot beneath the calcaneus was now seen to lie at the level of the neck of the talus. Although the pseudarthrosis had united, the bone showed signs of decreasing in width. The child was therefore hospitalized along with his mother, and under general anaesthesia the densely adherent and thickened periosteum was widely resected and an iliac cancellous graft from the mother was placed about the site of pseudarthrosis medially, posteriorly, and anteriorly (Fig. 6-F). Postoperatively, immobilization was again maintained by a toe-to-groin cast. The cast will be left on until union of the grafts has occurred at which time a brace will be prescribed.

Microscopic Examination

Tissue removed at the initial operation showed fibrous tissue within which there were two areas of bone. Within the bone, marrow cavities were noted. The bone appeared to be active osteogenically, but some of the marrow spaces were filled with soft fibrous tissue.

Tissue removed at the second operation (insertion of the medullary nail) showed, again, portions of fibrous tissue in which were noted granulation tissue, and fragments of bone and cartilage. The bone here was seen to taper to a point, was very dense and sclerotic and on the tip

Fig. 6-A Fig. 6-B Fig. 6-C

Fig. 6-A: Case 11. Original pseudarthrosis.
Fig. 6-B: Roentgenogram at operation, a dual onlay graft.
Fig. 6-C: Seven months after the dual onlay graft. Bone has been absorbed at the site of pseudarthrosis, and pseudarthrosis is recurring.

FIG. 6-D

FIG. 6-E

FIG. 6-F

Fig. 6-D: Insertion of a triangular medullary nail and application of an autogenous fibular onlay graft.

Fig. 6-E: One year after medullary nailing. There is union, but thinning of the cortex, and the distal tibia has grown in length so that the distal end of the nail now lies at the level of the neck of the talus.

Fig. 6-F: Reinforcing grafts have been placed about the constricted portion of the tibia; the medullary nail is left undisturbed.

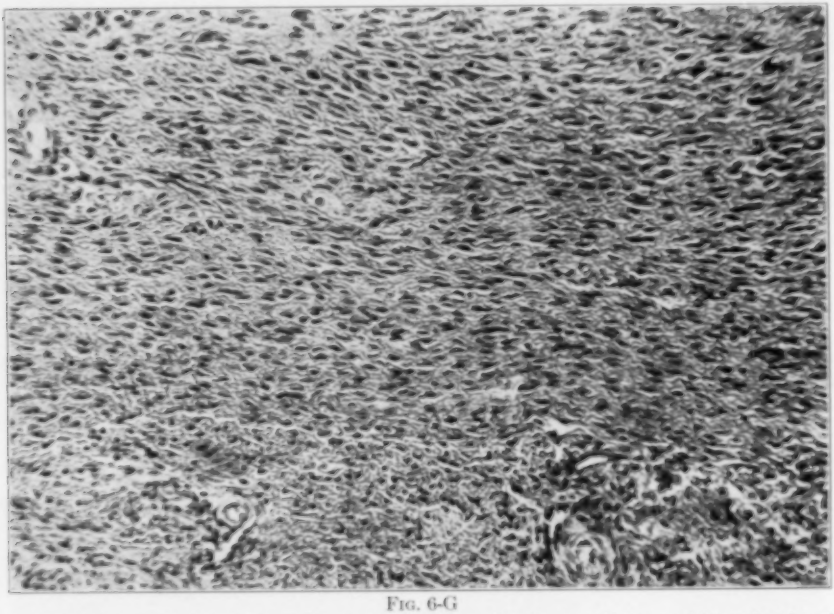

FIG. 6-G

Photomicrograph of material referred to as "thickened periosteum," removed from the site of pseudarthrosis. This highly cellular fibroblastic tissue is referred to as hyperplastic connective tissue and resembles histologically the tissue of fascial fibromatosis. The poorly demarcated plane of tissue at the bottom of the picture, which contains the two small arteries, represents the peripheral confine of the proliferating fibroblastic tissue and is continuous with periosteum. This is typical of the tissue found in those cases in which there is a narrowing of the bone.

was covered by irregular hyaline and fibrocartilage. The connective tissue was not unusually cellular but did show a foreign-body reaction. No neurogenic elements were seen.

Tissue removed at the third operation showed a markedly thickened periosteum in which were embedded small trabeculae of bone. Again a foreign-body reaction in the fibrous tissue was noted.

CASE 12. J. G. B., an infant white boy, was seen at birth by a member of the staff at the Clinic because of marked shortening and angulation of the left lower extremity. Roentgenograms at that time showed an absence of the lower portions of the tibia and fibula; the proximal half of the tibia and fibula were stunted, with tapering of the bone ends. No other congenital anomalies were seen; there were no *café-au-lait* spots. The child was followed with periodic roentgenograms, and, at the age of seven months, ossification of the distal portions of the tibia and fibula had begun to appear. The child's extremity was maintained in corrective casts for about three years, at which time there was anterior angulation of the lower portion of the leg with two and one-half inches shortening of the left lower extremity The distal tibial and fibular diaphyses failed to grow in length. Because of the deformity and failure of the leg to grow in length, a below-the-knee amputation was done October 21, 1957, when the child was three years old.

Microscopic Examination

The amputation specimen showed sclerotic tapering bone ends, between which lay proliferative fibrous tissue, in the center of which was a joint space lined with synovial membrane.

The pathological study of this specimen will be reported in detail at a later date by the Division of Pathology and Microbiology of the University of Tennessee Medical Units.

CASE 13. H. L. C., a white girl, was one of twins; her twin was entirely normal, and three other normal siblings were present in the family. She was first seen at the age of three months because of a deformity with obvious pain in the left lower extremity. Roentgenograms at that time revealed a typical pseudarthrosis of the left tibia and fibula at the junction of the middle and distal thirds. *Café-au-lait* spots were noted over the trunk; but there were no other stigmata of neurofibromatosis, although the father showed clinical evidence of neurofibromatosis.

On January 7, 1958, a modified Sofield procedure [13] was done on the child's left lower ex-

tremity: the pseudarthrosis was resected up to good bone, the upper portion of the tibia osteotomized, and the upper tibial fragment reversed so as to place good metaphyseal bone next to the proximal end of the distal fragment. In addition, a homologous graft of cancellous bone was placed between the osteotomized fragments to overcome the gap left by removal of the pseudarthrosis. A Steinmann pin was inserted retrograde out the distal fragment through the sole of the foot, then proximally through the osteotomized segment and cancellous graft, and into the proximal fragment. A double hip spica was applied. The child had an uneventful postoperative course and was discharged on January 21, 1958.

Microscopic Examination

Examination showed that the site of the pseudarthrosis had been resected and the two ends of bone came to fairly sharp points. There was minimal osteoblastic activity around the tips of the bones. The striking feature was a large mass of very cellular fibrous tissue, which seemed to be confined, in part at least, by somewhat expanded periosteum; the periosteum, however, appeared to have been split longitudinally by this mass of cellular connective tissue. This tissue had a dumbbell or collar-button shape, with the larger portion on either side lying over the area of pseudarthrosis and adjacent bone, and the smaller portion extending into and constituting the pseudarthrosis. This tissue was highly cellular, arranged in whorls and bundles, and, as commented before, bore a striking resemblance to the tissue of fascial fibromatosis. In the mid-portion, however, between the two bone extremities, small irregular but well-formed synovial spaces were seen.

Case 14. D. F., a Negro girl, twenty-two months old, was first seen by members of the staff of the Campbell Clinic in November 1957. The child was a ward of the Public Welfare Department, but her mother, seen later, said that at the age of approximately one year a deformity of the lower portion of the child's left tibia had been noted and that she had been referred to the Tennessee Crippled Children's Service. The child was there seen by an orthopaedic surgeon who advised that the operative procedure be delayed for approximately one year, at which time she was to return to be seen by a member of the staff of the Campbell Clinic. On her initial examination here, there was a fixed pseudarthrosis with anteromedial bowing at the junction of the middle and distal thirds. The child had been walking without pain. Several *café-au lait* spots were noted on the trunk and buttocks. On December 12, 1957, the child and her mother were hospitalized, and dual onlay grafting was accomplished the following day with bone from the mother's tibia and internal fixation with four stainless-steel screws. Postoperatively, immobilization was maintained by a toe-to-groin cast. A mild postoperative wound infection with a slough of skin of approximately 1.5 centimeters in diameter developed directly over the area of previous pseudarthrosis. This gradually healed and at three months postoperatively, March 13, 1958, the child was being maintained in a hip spica cast.

Microscopic Examination

A small cyst which was removed from the subcutaneous tissue over the pseudarthrosis was lined with synovial cells, and was undoubtedly an adventitial bursa. The other tissue removed from the site of pseudarthrosis was in large fragments, and orientation was difficult to interpret. There were irregular segments of rather sclerotic bone about which little activity, either osteoblastic or osteoclastic, was seen; these were embedded in rather dense, cellular, hyperplastic fibrous tissue in a nodular or lobular form, which in some areas seemed to be undergoing a mucoid or chondroid change.

Case 15. R. A. McG., a four-month-old white girl, was first seen at the Campbell Clinic on November 23, 1953, at which time a mass was noted in the left leg. This had been noted initially one month prior to examination and had been thought by the parents to have doubled in size during the month of observation prior to her first visit to the Clinic. On examination, the child had no birth marks, *café-au-lait* spots, or other stigmata of neurofibromatosis over the body, except perhaps for the mass in the leg. This was a soft-tissue mass ten by five centimeters over the upper anterior third of the left tibia. It did not clinically involve the knee joint. The mass, clinically, was non-cystic and firm, and seemed to blend with surrounding fat. Roentgenograms made at the time of the Clinic visit revealed a cystic lesion at the junction of the middle and distal thirds of the left leg with anterolateral angulation of the tibia and fibula at this site. In addition, a soft-tissue mass was seen occupying the entire upper half of the left leg below the knee. It was felt that the soft-tissue mass was either neurofibroma or lipoma. The day following examination the child was admitted to the hospital. The soft-tissue mass was excised with sharp dissection; it was found to be encapsulated with an attachment to the crest of the tibia anteriorly and to the muscles of the anterior compartment of the leg as well. The cystic defect in the tibia was curetted and packed with bone. The mass was subsequently diagnosed as rhabdomyosarcoma, and the microscopic picture produced by tissue from the cystic lesion was described as that of fibrous dysplasia.

Amputation was done through the upper portion of the thigh. The amputation stump healed readily and the child was followed at monthly intervals on an out-patient basis. Roentgenograms of the chest made on October 18, 1954, nine months postoperatively, showed definite metastases to the lungs. The child expired shortly thereafter.

This we feel is a rather strange coincidental occurrence of rhabdomyosarcoma—the tissue of the tumor showing definite striations microscopically—and fibrous dysplasia in a pre-pseudarthrotic area of the left tibia and fibula.

DISCUSSION

Pathogenesis

Since the first description of congenital pseudarthrosis by Hatzoecher in 1708 [21], numerous theories of etiology have been advanced. For the most part, earlier theories suggested intra-uterine trauma, such as embryonic constricting bands, abnormal compression of the skeleton of the foetus by the amnion [18,31], constriction by amniotic adhesions [16,26], and even trauma from the outside [17]. These, over the years, have been discarded. As the foetus and the amniotic fluid are of essentially the same specific gravity, it is inconceivable that external violence could produce only localized injury [41]. Theories related to generalized metabolic disturbances [28] have likewise been cast aside [24], since studies of the affected children have failed to reveal any generalized nutritional or metabolic disturbance [22,29]. Heredity [18] at one time was advanced as the possible cause, but to date in the English literature, only one instance of more than one case in the same family [27] (a maternal first cousin) has been reported. Vascular abnormalities in the lower extremities have likewise been suspected [10], since specimens dissected following amputation have been known to show a microscopic picture of endarteritis [36]. It has been theorized that a defect in the nutrient artery to the tibia [11,23,40] might be the cause. However, from the studies of Trueta [44] and from the modern use of medullary nails, which must undoubtedly interrupt the blood supply from the nutrient arteries to the bones in most instances, we have learned that the presence of an intact nutrient artery is not a necessary factor for bone healing. If the nutrient artery is defective in congenital pseudarthrosis, it would not impair the blood supply to the periosteum and the outer one-third of the cortex of the tibia.

Since the work of Duraiswami [14], endocrine abnormalities have been advanced as the possible cause. However, it hardly seems reasonable that endocrine abnormalities would affect only one side of the skeleton during its formative growth. In Duraiswami's insulin-induced pseudarthrosis in chick embryos, the cases illustrated showed bilateral symmetrical involvement. To date only one case of bilateral congenital pseudarthrosis of the tibia has been recorded in the English literature [29], and Camurati, in reviewing 145 cases from the world literature, found only 4.5 per cent bilaterally involved [5]. Two of our patients had congenital pseudarthrosis of the tibia and fibula on one side and of the fibula on the other.

It has been often observed that there is a definite relationship between congenital pseudarthrosis of the tibia and neurofibromatosis [32], and it is inferred by several authors [4,19,27], that the pseudarthrosis is due to an extra-osseous or an intra-osseous neurofibromatous mass. In the English literature, only two cases of intra-osseous neurofibroma at the site of a congenital pseudarthrosis of the tibia have been recorded. The case reported by Green and Rudo [19] showed intra-osseous neurofibroma at two levels, the tibia having fractured first at one level and later at the other. At both operative procedures, tissue was removed which was interpreted as an intra-osseous neurofibroma. The other case appears to be less well substantiated. Jacobs, Kimmelstiel, and Thompson [27] postulated in this case that "actual destruction of bone by subperiosteal or intraosseous neurofibromas with so-called subperiosteal cysts must be assumed as the cause of fracture" (p. 236); however, the microscopic picture of the tissue removed from the site of congenital pseudarthrosis in that case showed "well formed lamellar bone in continuity with a large mass of connective tissue. This latter enclosed small fragments of necrotic bony spicules and a small area of new formation of bone by direct metaplasia" (p. 235). No staining for nerve fiber

was done, but the authors concluded that the pathological diagnosis was neurofibroma. In retrospect, this patient, who had *café-au-lait* spots, enlargement of the clitoris, and intracortical cystic lesions above the fracture site, would appear to exemplify Albright's disease.

Of 178 cases of reported congenital pseudarthrosis of the tibia from the Shriners' Hospitals of North America, seventeen were said to show neurofibromatosis "at the site" of the congenital pseudarthrosis [40]. However, the exact site—that is, whether intra-osseous or extra-osseous—is not recorded.

The incidence of von Recklinghausen's neurofibromatosis and pseudarthrosis of the tibia occurring simultaneously is certainly frequent enough to lead one to believe that there is a definite relationship between the two. B. H. Moore, in studies on nerves of seventy-eight patients with various congenital deformities [37], found pathological changes in the microscopic sections of the peripheral nerves in 91 per cent of the seventy-eight cases. In an earlier paper [36], he had stated that the condition of the nerves in pseudarthrosis stood in the relation of cause and effect, although the mechanism of production was not entirely clear.

Since the microscopic picture of fibrous dysplasia was seen in two of our patients in the tissue between the bone ends, it is of interest to note that Aegerter [1] suggested that three conditions—neurofibromatosis, congenital pseudarthrosis, and fibrous dysplasia—are in some way related. He feels that in neurofibromatosis there are both true neoplasms, such as neurilemoma, melanoma, and glioma, and hamartomatous proliferations, such as the bundle pattern of fibrocytes described in plexiform nerve lesions and pedunculated skin tumors. In microscopic sections examined from congenital pseudarthrosis of the tibia, he states that there is a hamartomatous proliferation of fibrous tissue (leading some to mistake it for neurofibroma) which undergoes metaplasia into poor or disorganized bone; the lesion of fibrous dysplasia (like those in pseudarthrosis) represents an inability to produce normal bone in one or more areas with metaplasia into primitive bone. The fibrous proliferation of the latter two conditions are unlike the true tumors of neurofibromatosis, but quite similar to the hamartomatous structures of that disease. Aegerter suggested that these curious fibroblastic masses have a common cause in all three conditions, that is, an alteration in the nerve pathways to these areas which produces abnormal growth and maturation of the tissues supplied. He gained further support for this theory from the finding by B. H. Moore [36] of a neurofibromatous mass in the posterior tibial nerve in a patient with congenital pseudarthrosis of the tibia.

Aegerter's description of the pathology of the tissue found between the bone ends of the tibia in congenital pseudarthrosis seems to correlate well with the majority of the reported pathological studies in the literature; that is, an abnormal mass of fibrous or fibroblastic tissue interposed between sclerotic bone ends in which occasional bone trabeculae, poorly formed cartilage, or fibrocartilage is seen. It could well account for the thickened periosteum which McElvenny [33] believes is the etiological factor and which we have observed in each patient operated upon since reading his interesting report.

Reports of cystic lesions at the site of the pseudarthrosis are not at all unusual in the literature [6, 7, 12, 13, 19, 22, 26, 27, 29, 33, 35, 42, 45, 46, 47]; such lesions were observed in three or four of our patients: Cases 4, 9, and 15, and probably Case 1. One cyst of the tibia (in Case 9) was curetted and packed with bone chips prior to an impending fracture, and the pathological description was consistent with that of fibrous dysplasia. In this patient a pseudarthrosis of the fibula subsequently developed.

A recent review of the pathological reports of fourteen of the fifteen patients revealed the presence of this proliferative fibrous tissue with occasional bone trabeculae and poorly formed hyaline or fibrocartilage, along with a markedly thickened periosteum. There were two exceptional cases: Case 12, in which a true joint cavity lined with synovial cells was found between the bone ends, and Case 13, in which synovial spaces were also found in the fibrous tissue between the bone ends. It should be added that in Case 12, the roentgenograms were also

atypical. In none of the fourteen patients have neurofibromata been found in fragments themselves, although either *café-au-lait* spots or neurofibromatous skin nodules were found in nine of our fifteen patients.

Of the six patients who did not show *café-au-lait* spots or neurofibromatous skin nodules, the mean age was five years; the extremes were one and twelve years of age, and it is possible in these that neurofibromatous skin nodules may develop later.

Pathologically, there are two major types of congenital pseudarthrosis of the tibia. In the first, a cystic lesion occurs in the lower third of the tibia, the microscopic pathological pattern of which resembles fibrous dysplasia. In these patients the diameter of the tibia is not significantly narrowed. The second type is represented by those patients who have a marked narrowing of the diameter of the tibia with obliteration of the medullary canal and sclerosis. Tapering of the bone ends follows fracture. The gross pathological appearance in these is marked thickening of the periosteum, and proliferation of fibrous tissue about and filling the fracture site. The microscopic findings are consistent with that described by Aegerter as a hamartomatous proliferation of fibrous tissue. This is the more common type and more prone to non-union and refracture. The actively proliferating pathological fibrous tissue produces a tightly adherent constricting band about the site of pseudarthrosis, causing constriction of the bone with associated atrophy of the latter secondary to pressure. This thickened indurated band of fibrous tissue also diminishes the blood supply to the bone. Unfortunately, there is a marked tendency to re-formation of the constricting band following its excision and bone-grafting. Consequently, the factors producing the original pseudarthrosis continue to operate and are the underlying cause of refracture.

In view of the above inferred relationship of abnormal nerve pathways and congenital pseudarthrosis of the tibia, it is quite possible, as suggested by Badgley, O'Connor, and Kudner [3], that at some time during the fifth week of embryonic life, maldevelopment of the mesodermal structures of the leg occurs, secondary to abnormalities in the nerve pathways. This concept can be supported by the findings of B. H. Moore in his studies of peripheral-nerve changes associated with congenital deformities [37]. It is further substantiated by the work of Duraiswami [14], and by the fact that Bassetta [5] described an early pre-fracture stage of congenital pseudarthrosis of the tibia in a fourteen-week-old foetus.

Thus in approximately 430 cases which have been reported in the English literature during the last fifty years [40], we are now only a little closer to determining the pathogenesis than at the time of Codivilla's publication in 1907 when he postulated that it was due to an embryonal lack of development in the arterial supply to the bone [10].

Treatment

An appraisal of the literature for end-result studies on the management of congenital pseudarthrosis of the tibia is difficult, because relatively few patients have been reported following the attainment of skeletal maturity, and because end results of the operative procedures advocated should not be evaluated until after completion of bone growth. Since the ultimate aim is to have a socially and economically rehabilitated patient, end-result studies should include these two factors. A review of the entire literature in English relative to treatment shows that a variety of operative procedures have been advocated, each one usually by an author who is particularly interested in that procedure and whose results generally have been reported as an endorsement of his method. In this review, reports were found of ninety-one cases where either the operative age and the total follow-up period were stated, or the age at final follow-up could be determined. Of these ninety-one, only sixteen patients had reached skeletal maturity. Thus we have for appraisal from our point of view the end results for only sixteen patients. Of these, two had had a persistent non-union; a third had undergone amputation; and six had obtained union from an operative procedure the

type of which was not definitely stated although the author reporting them recommended a "sliding-end-under-boneflap-onlay graft" [29]. Excluding these, we have seven remaining patients in whom we know both the operative procedure performed and the fact that the patients had been followed to skeletal maturity. Of these seven, three had a massive single onlay graft of autogenous or homogenous bone: of these three, one had been followed for only two years [4], one for five years [12], and the third for twenty-two years [7]. Of the remaining four, two had had a by-pass graft [25] and had been followed postoperatively for fourteen and sixteen years respectively; and two had had a delayed graft and had been followed for over ten years [40].

TABLE I

Operative Procedure	Times Reported
Delayed bone-grafting	23
Massive tibial onlay grafting	21
Inlay grafting	19
Dual onlay grafting	18
Multiple bone transplantation (Hallock procedure)	13
By-pass grafting	11
Bone-flap onlay grafting	8
Two-stage fibular grafting	6
Open reduction and drilling	6
Amputation	4
Fragmentation and medullary nailing	4
Barrel-stave grafting and suturing	3
Diamond inlay grafting	3
Composite pedicle grafting	3
Osteoperiosteal grafting and medullary nailing	3
Cast application alone	3
Plate and bone-grafting	2
Bone-grafting (type unspecified)	2
Onlay grafting from normal opposite fibula	2
Transplantation of one end of fibula	1
Quadruple onlay grafting	1
Resection of periosteum	1
Onlay grafting from fibula, same side	1
Accessory procedures	9
Total	167

As well as we could determine, the ninety-one patients had been subjected to twenty-three varieties of treatment; the total number of procedures performed by the reporting authors was 167. (Note that this number does not include the procedures these ninety-one patients underwent before being treated by the reporting authors.) The results of the 167 procedures were reported as follows: union in ninety-four instances, and non-union in fifty-seven instances; in three instances, the result was classed as too early to evaluate at the time of reporting. Amputation was performed in four instances. Nine accessory procedures were performed either before or after the major procedure and were not directed toward securing union. Refracture of the previously united tibia was common.

The twenty-three varieties of treatment ranged from simple cast fixation alone (which was successful in only one atypical case [36] in which refracture subsequently occurred), to amputation; they included the most current approach as advocated by Sofield [43], multiple osteotomy, and medullary nail fixation of the affected tibia. For the most part, all operative procedures had been directed toward obtaining either an autogenous or a homogenous graft to bridge the affected area. The relative frequency of the operative procedures done by authors reporting in the English literature, regardless of length of follow-up, is given in Table I.

Almost all of the operative procedures have their advantages, but all, likewise, have their disadvantages. Simple cast immobilization has not been reported as successful in any case of true congenital pseudarthrosis. Amputation is the easy solution to a difficult problem, but aesthethically and anatomically is not acceptable to the average parent. The use of a massive onlay graft from the opposite tibia involves the risk of weakening the unaffected tibia, and the possibility of fracture. The composite pedicle transfer procedure [15], besides being technically difficult, is fraught with the possibility of infecting the unaffected leg. The delayed autogenous-bone graft [40] depends upon hypertrophy of a small graft or upon multiple reinforcement of the grafted area to obtain a tibia large enough to be free from danger of refracture, and requires two operations on the unaffected leg. Use of the opposite fibula as an onlay graft has not been reported to be successful with any frequency. The fibula on the same side is usually not suitable for an onlay graft because it is small and may also have a pseudarthrosis. The two-stage fibular transplantation [25, 47] requires two operations, and depends on hypertrophy of a small bone or repeated reinforcement in order to obtain a tibia large enough to withstand weight-bearing. When multiple chip grafts are used alone [20], either from the affected tibia or from the ilium, fixation of the fragments depends upon cast immobilization. This method has not been successful in a majority of the cases. Wide resection of the periosteum [33] has been reported successful in one case; here again, fixation of fragments depends upon cast immobilization alone. The use of barrel-stave grafts [10] has a similar disadvantage. When an inlay graft [2] from the same tibia is used, the graft is too small and the internal fixation is inadequate. The by-pass graft [35], reported successful in nine out of eleven cases, may result in an angulated and shortened tibia. The boneflap onlay graft was reported successful in seven out of eight cases [29], but here again, immobilization depends primarily upon cast fixation. The dual onlay graft [6,7] has been said to be technically difficult; it also requires the acceptance by the host of homologous bone, since in order to obtain cortical bone of adequate size a bone donor must usually be found, unless the patient is near the age of puberty. Another disadvantage is the difficulty in securing fixation of the grafts to the distal fragment when the site of pseudarthrosis is near the distal end of the tibia.

No matter which operation is performed, the affected tibia is prone to refracture until skeletal maturity is reached. For this reason, the use of medullary nails as advocated by Charnley [9] and Sofield [43] has the advantage of continuous internal fixation over a long period of time, and thus the danger of refracture is less. However, it also has the danger of damage to the ankle joint or to the distal tibial epiphysis.

Our fundamental philosophy of the treatment of congenital pseudarthrosis has changed during the past ten years. Previously, we have recommended that operative treatment be delayed until the child is three to five years old. Our present policy, however, is to begin operative treatment as soon as anaesthesia and an operative procedure of this magnitude can be done safely. This prevents the establishment of marked shortening and deformity, and early use of the extremity minimizes retardation of growth. We also explain to the family that treatment consists in multiple operations similar to the multiple operations required in the rehabilitation of patients with several other types of orthopaedic conditions. Further, in those patients with pseudarthrosis who are seen prior to fracture with cystic lesions and anterolateral angulation of the leg, we advocate early treatment consisting in curettage of the cystic lesion and placing bone grafts in the defect, followed by cast immobilization until the defect is obliterated and a tibia of adequate size achieved. This has been done in two patients reported here, and we feel that in another patient a true congenital pseudarthrosis of the tibia might have been prevented by these prophylactic measures. If the cyst shows evidence of recurrence, the area should be recuretted and packed with bone chips. We also believe that dual onlay bone-grafting is the initial treatment of choice in those patients with established pseudarthroses, provided that the distal

fragment is long enough to permit placement of the screws at an adequate distance from the pseudarthrosis.

In those instances in which the distal tibial fragment is too short for adequate fixation with cortical grafts, the use of medullary fixation and bone-grafting is indicated, either by the method of Charnley [9] (Case 11) or that of Sofield [42] (Case 13). These stabilize the fragments adequately and allow wide resection of the pathological fibrous tissue; and Sofield's method places relatively normal bone at the site of previous pseudarthrosis. Additional bone may be packed about the site to increase the diameter of the tibia. Wide resection of the constricting fibrous tissue band should be employed before the application of a dual graft or before the use of medullary fixation.

The subsequent treatment is one of repeated observation roentgenographically and clinically. If at any time the tibia shows evidence of narrowing or sclerosis of the cortex or medullary canal, wide resection of the constricting periosteal sleeve and reinforcing grafts are indicated, to increase the diameter of the tibia and to produce a barrier inhibiting the re-formation of the constricting fibrous tissue.

Recommendation

A registry of congenital pseudarthrosis of the tibia should be established. The personnel in charge should include members of our specialty and allied sciences bearing on this condition, such as pathology, embryology, and physiology. All relevant information should be channeled to this registry, including case histories, operative findings, microscopic pathology, and clinical follow-up through skeletal maturity. Study of a large series of well documented cases placed in such a registry would improve our knowledge far more effectively than any one small group of orthopaedic surgeons can now do.

CONCLUSIONS

1. There are two distinct types of congenital pseudarthrosis of the tibia. In the first, a cystic defect, with or without fracture, is present and the pathological findings resemble those in fibrous dysplasia. The second shows sclerosis and tapering of the bone ends, probably due to a constricting band of fibrous tissue. In this type, union is more difficult to secure.

2. The etiological factors are still undetermined, but are probably due to a maldevelopment of the mesodermal structure during the fifth week of fetal life, with an associated abnormality occurring in the nerve pathways to the affected leg.

3. Pathological studies of material obtained from within the bone and between the bone ends at the site of pseudarthrosis are notably lacking in the literature. Each specimen excised should be thoroughly studied.

4. Early surgical treatment before the development of marked deformity is advised. In the first type the cyst should be curetted and the defect filled with bone chips; additional bone-grafting may or may not be necessary. In the second type, a wide resection of the constricting band of pathological soft tissue should be done, combined with suitable bone-grafting and adequate internal and external fixation; the latter, achieved by casts followed by suitable braces, should be continued until skeletal maturity or until a tibia of relatively normal size develops.

5. In cases with extreme deformity, amputation may be indicated when one is reasonably sure that a prosthesis will provide a better weight-bearing extremity than the best extremity that could be obtained following successful reconstructive surgery. In making the decision, the surgeon should compare the function of an artificial leg with the best result that can reasonably be expected following reconstructive surgery, not with a normal extremity.

6. Repeated clinical and roentgenographic examinations should be continued until skeletal maturity is reached. If at any time evidence of narrowing of the bone or sclerosis of the medullary cavity appears, prophylactic operative

intervention with wide resection of the constricting band of scar tissue should be done. In addition, reinforcing grafts should be placed about the area of previous pseudarthrosis.

7. Multiple operations may be necessary during the growth period.

8. A registry for congenital pseudarthrosis of the tibia is needed in order to enhance our knowledge of its etiology, pathology, treatment, and end results through the age of skeletal maturity.

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Vascular Injuries in the Orthopaedic Patient

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In the past, arterial injuries complicated by fractures and extensive soft-tissue destruction, especially of the popliteal area, often have been an indication for amputation. While patients with combined orthopaedic and vascular injuries are seen in increased numbers during war or disaster, frequent cases are reported in the literature from civilian practice. Certainly the reported cases represent only a percentage of those treated. Although the trend over the past few years has been toward reconstructive vascular surgery, occasional cases still are reported in which obliterative vascular techniques are practiced. While there are several instructive papers published on the subject of vascular injuries [5,7,13,14,23], it is the purpose of this paper to discuss further the practicability of blood-vessel repairs in the presence of orthopaedic injuries.

CAUSES AND INCIDENCE OF VASCULAR INJURIES

As a rule, civilian injuries are not as destructive as those seen in battle casualties. Various investigators have reported on battle-incurred vascular injuries from both World War II [25] and the Korean War [6,10,11,22]. While most damaged blood vessels were ligated during World War II, the practicability of repair of acute blood-vessel injuries was proved under conditions which existed in Korea where the amputation rate following arterial repair was decreased from 36 per cent in World War II to 13 per cent [8]. While the majority of these vascular injuries reported had no accompanying bone involvement, many had additional nerve and soft-tissue destruction.

DeBakey and Simeone [25] reported that during World War II the incidence of amputation was significantly higher when the acute vascular injury was complicated by a fracture. Most of the vascular injuries comprising their report were treated by ligation. Although no specific percentage of fractures in acute arterial injuries from World War II is stated, Elkin and Shumacker [25] reported the presence of thirty-eight associated fractures in 159 patients with traumatic aneurysms and ninety-nine fractures in 288 patients with arteriovenous fistulae (31 per cent incidence of fractures accompanying these lesions).

Individual investigators in Korea reported various percentages of fractures accompanying vascular injuries. Spencer and Grewe [22] found twenty fractures accompanying fifty-four cases with popliteal and femoral-artery injuries (37 per cent incidence of fractures). Limb loss from gangrene was considerably higher in those cases with concomitant fractures. Jahnke and Seeley [11] reported eighteen fractures accompanying thirty-two major vascular injuries (an incidence of 56 per cent). The author [6] noted compound fractures associated with only 15 per cent of a series of seventy-nine acute vascular injuries. Morris, Creech, and DeBakey in reporting a large series of acute vascular injuries occurring in civilian life noted the presence of fractures in thirteen of 129 patients (10 per cent).

In addition to studying vascular injuries resulting from missiles in Korea, the author has had occasion to repair surgically a number of vascular injuries in orthopaedic patients. Fractures of the pelvis have been observed to damage the iliac arteries by severing and impinging the vessels. In one patient, pelvic fragments damaged the external iliac artery breaking only the intima circumferentially which became involuted obstructing the artery and requiring resection and anastomosis. Other injuries observed and treated included those occur-

ring in the operating room such as injuries to iliac arteries and veins during surgery for intervertebral-disc disease and injury to the axillary artery during reduction of a fracture of the neck of the humerus. Among the more common injuries observed have been severe arterial spasm, spasm and thrombosis, severance, and compression of the artery by fractured bones.

The recent orthopaedic literature contains reports of various types of vascular injuries in orthopaedic patients [1,4,26]. These include vessel disruption, thrombosis, and spasm resulting from fractures [21]. Dislocation of shoulders, elbows, and knees not infrequently results in disruption or thrombosis of vessels [2,3,15,24]. Damage to vessels from axillary crutches is not unusual and may result in thrombosis or aneurysm formation [18].

TYPES OF ARTERIAL INJURIES

The majority of arterial injuries occur as open wounds of the vessel in which the vessel may be lacerated, may be severed, or may have a portion

FIG. 1

In addition to a severed brachial artery, many collateral vessels also are destroyed in this large soft-tissue wound. The defect in the artery was repaired by an autogenous-vein graft (Fig. 5).

avulsed. Open vessel wounds usually are seen in the presence of open soft-tissue injuries resulting from gunshot, sharp weapons, or vehicular accidents. However, the same injuries may occur to the vessel wall without visible evidence of soft-tissue damage. Laceration of the vessel by the end of a fractured bone is probably the most common cause of disrupted vessels in a closed soft-tissue compartment. A sharp blow over an artery can create an open vascular wound without breaking the skin. Similarly, the dislocation or reduction of a dislocated joint may rupture a major artery without evidence of soft-tissue destruction. While hemorrhage at the site of injury and ischaemia distal to the injury may occur, the violence of the injury, on occasion, may sever the vessel; and contraction of the severed ends may be such that hematoma formation may be minimal. In the closed soft-tissue wound, the degree of hematoma is indicative of injury and the amount of blood lost. Such is not always true in the open soft-tissue wound.

The second major group of blood-vessel injuries includes the closed vessel injuries or those in which the wall of the vessel is not broken through. Such acute arterial occlusion may occur in the presence of open or closed soft-tissue trauma and may be initiated in various ways. Spasm, frequently accompanying a fracture or initiated by contusion, stretch, or other trauma to some part of

the vascular tree, may occlude an artery for an indefinite period of time and result in thrombosis or irreversible ischaemic changes. Contusion of the vessel may break the intima and initiate thrombosis or permit dissection and involution of the intima with occlusion of the vessel. An artery may be occluded mechanically by a hematoma or swelling within a tight fascial compartment or by compression between bone fragments. An embolus may block a vessel resulting in spasm and ischaemia. While an embolus commonly lodges at a bifurcation or at the origin of a major branch of a vessel, the resulting spasm often makes it difficult to determine the level of the embolus.

COMPLICATIONS AND THEIR PREVENTION

The most serious complications of arterial injuries are those which endanger life. This danger exists primarily in those patients with open vascular injuries in whom the initial threat to life comes from exsanguination. Open injuries to large vessels usually result in considerable blood loss and, even though fatal

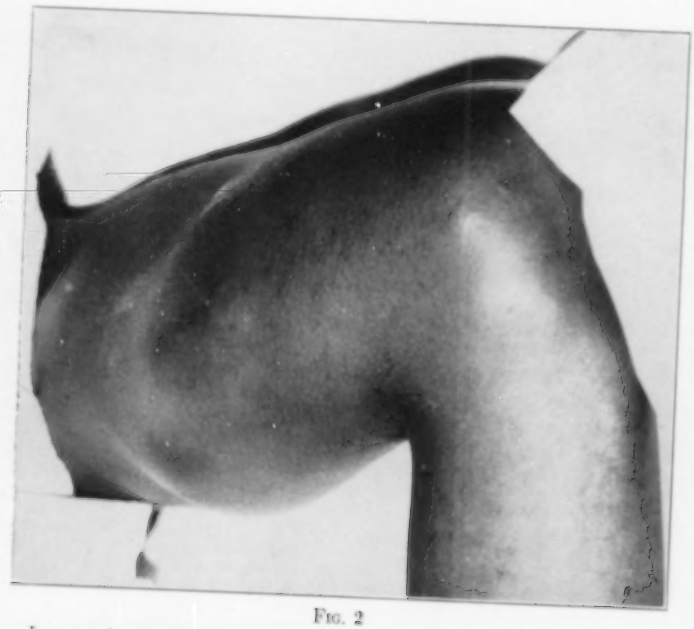

FIG. 2

Large pulsating hematomata as this from an injured superficial femoral artery may be self-controlled indefinitely or may expand with damage to surrounding structures or hemorrhage.

hemorrhage is avoided, the resulting shock and its complications, if improperly treated, may result in loss of life. In three reports[6,11,16] of groups of patients with injuries to major arteries, it was noted that 38 to 66 per cent of the patients were admitted to the hospital in shock.

The control of hemorrhage as a lifesaving measure is the primary treatment of the patient with open wounds of blood vessels. Such control may be applied as one of many forms known to the surgeon. The use of pressure dressings is the most desirable means of controlling hemorrhage since it usually is effective and, by allowing existing collateral vessels to continue to function, helps to preserve the limb. The use of a tourniquet hampers the flow of blood through collateral vessels and when used improperly or over a prolonged period of time may result in irreversible ischaemic changes.

An artery which is severed tends to contract and retract which helps to

control the hemorrhage. Even though the hemorrhage may cease spontaneously, there is always danger of secondary hemorrhage if proper control is not applied.

Of secondary importance only to the control of hemorrhage is replacement therapy for the individual in shock. A thorough evaluation of all injuries and rapid and complete resuscitation in preparation of the patient for surgery are further insurance against additional complications.

The vasoconstrictive action of shock, while protective to the organism, is injurious to an already ischaemic limb. Vasospasm and low blood pressure complicate arterial occlusion and hasten the onset of gangrene. This is just further indication for immediate and complete resuscitation of the patient in shock. The use of vasoconstrictor drugs in patients with an ischaemic extremity is contra-indicated. The usefulness of such drugs in patients in hemorrhagic shock is questionable and further vasoconstrictive action in an already ischaemic limb may cause additional harm. The use of vasodilator drugs intra-arterially in the ischaemic extremity is also of doubtful value and may, on reaching the general

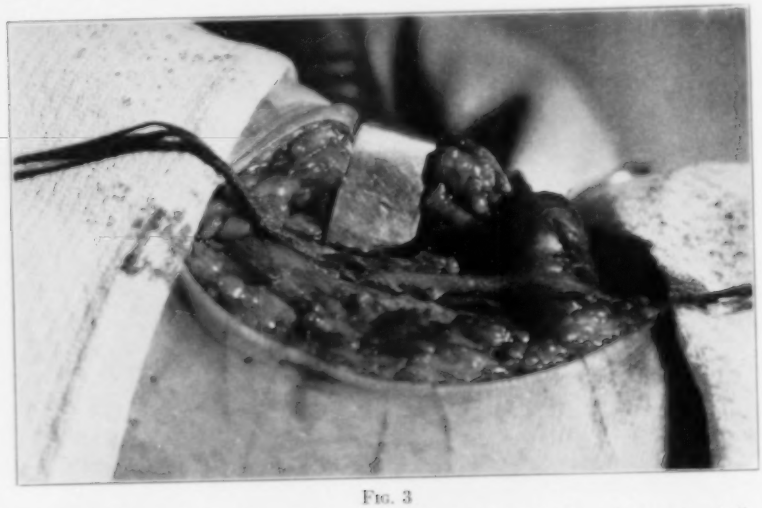

FIG. 3

This dumb-bell shaped false aneurysm resulted from a through-and-through missile wound of the brachial artery. After excision, the artery was repaired by direct anastomosis.

circulation, add to the difficulties of resuscitation of the patient. Heat to ischaemic limbs is contra-indicated since it will increase the rate of metabolism and the oxygen demand. Cooling an extremity is beneficial to a degree, preferably by leaving the extremity uncovered and exposed at room temperature. Preoperative sympathetic blocks to such an extremity are not indicated. The time required for such a procedure should be devoted to the more rapid preparation of the patient for surgery.

The next most serious complication to occur is ischaemia to an extremity with resulting gangrene. In the hands of a trained vascular surgeon, this complication is usually the result of the time lag from injury to surgery. In addition to the ischaemia resulting from disruption of a major vascular channel, the minor or collateral channels also may be involved. Soft-tissue wounds result in the destruction of collateral vessels (Fig. 1). Excellent collateral channels exist in some bones and are disrupted by fracture.

Time lag from injury to surgery is probably the greatest complicating factor resulting in limb loss. This factor can be improved only by faster methods of transportation and more rapid resuscitation of the injured individual. In addi-

tion to decreasing the time lag, actual care of the ischaemic extremity is important in preventing irreversible changes. This care of the extremity begins with resuscitation of the patient. By replacing the blood lost and returning the blood volume and blood pressure to normal, ample oxygenated blood is made available to nourish the ischaemic limb through any remaining vascular channels. Existing collateral channels often are adequate for limb viability if allowed to function. It is for this reason that tourniquets and mechanical compression of any kind, except that necessary for the control of hemorrhage, should be avoided. While it is well to immobilize such an injured extremity, any splint or basket used should be well padded.

An ischaemic extremity usually shows absence of pulse, empty veins, and pallor; it is cold and painful. Later it may show dependent lividity, become anaesthetic and paralytic with spastic Volkmann-like contracture. Such ischaemic spasm may result from periods of partial or complete ischaemia. With return of blood supply the previously anoxic muscle often becomes oedematous

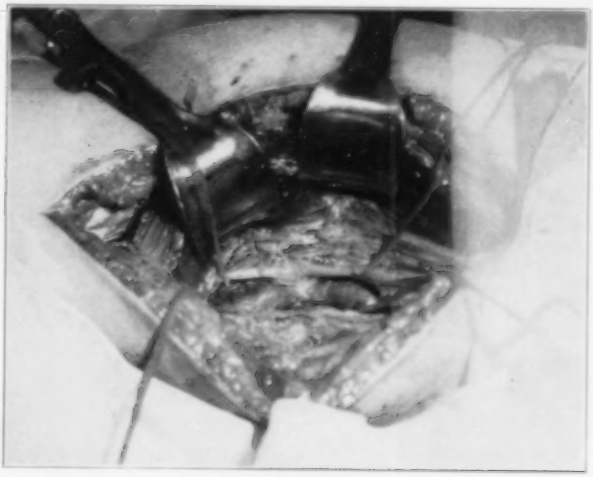

FIG. 4

Here a simple traumatic arteriovenous fistula is exposed with control tapes placed on both vessels prior to excision of the fistula with direct anastomosis of the artery and repair of the vein.

and swollen. Irreversible muscle changes within tight fascial compartments may result unless decompression is afforded by fasciotomy. The anterior tibial compartment of the leg and the flexor compartment of the forearm are quite susceptible to these changes. Failure to recognize such changes may result in permanent nerve damage, muscle necrosis, compartment, or even limb, loss.

Vessels which are incompletely severed continue to bleed and a patient can bleed to death by blood loss into his own thigh. If, however, the blood becomes trapped by planes of fascia, muscle, bone, and skin, a pulsating hematoma may be created (Fig. 2). If left undisturbed by surgery, expansion, or infection, such an injury of an artery alone will develop into a false aneurysm (Fig. 3). If an artery and vein are injured under the same circumstances, an arteriovenous fistula develops with flow of blood directly from the artery to the vein limiting the amount of peripheral blood flow distal to the fistula (Fig. 4). Unlike most types of arterial injuries, a peripheral pulse usually is palpable in the presence of these lesions.

The presence of traumatic aneurysms and arteriovenous fistulae may cause further complications. Large traumatic arteriovenous fistulae between vessels of

iliac size may result in cardiac decompensation. Peripheral arteriovenous fistulae rarely cause cardiac complications. Complications resulting from traumatic aneurysms are usually local and often consist of expansion with pressure on adjacent structures or rupture of the false sac with hemorrhage. In some instances comminuted bone fragments at a fracture site or a portion of bone may make up part of the false sac. The pulsation of an aneurysmal sac may erode bone or destroy adjacent nerves. Nerves and bone exposed to the jet stream of blood within the sac may be denuded and damaged.

OPERATIVE CARE

Vascular injuries are surgical emergencies. The urgency of the surgery varies with the type of injury and the vessel involved. Delay or indecision as to treatment may result in loss of limb or life. For that reason, resuscitation, evaluation of injuries, and restoration of blood supply should be accomplished at the earliest possible moment. After proper exposure and control of the involved vessel, repair may be accomplished in one of several ways, depending on the type and severity of the injury. A minimal laceration of a vessel wall which requires no débridement may be repaired by simple suture after determining that no thrombus extends into the lumen. More severely injured vessels require débridement with anastomosis when possible. When a defect exists, too great for apposition of the vessel ends, then a graft of homologous artery, autogenous vein, or possibly woven plastic material is indicated (Fig. 5). Such repairs are satisfactorily performed using 00000 arterial silk as interrupted sutures or as a continuous everting or simple suture. While the interrupted suture line may leak, the continuous suture may result in constriction of the vessel lumen if the suture is pulled too tightly (Fig. 6). Excess tension on the ends of the vessel may result in spasm or separation of the suture line. After the repair of the vessel and

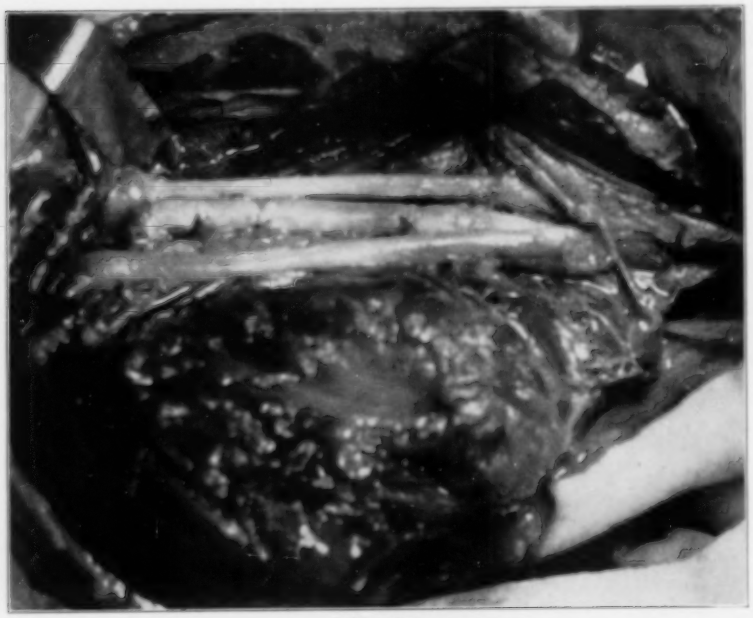

FIG. 5

Large vascular defects may be bridged by homologous-artery grafts, autogenous-vein grafts, and, in some instances, by woven plastic prostheses. Here an autogenous vein has been reversed and placed in the arterial defect (Fig. 1).

débridement of the wound are completed, the vessel must be covered with the surrounding tissues for nourishment and for protection from drying and infection. In cases of open trauma, it is safer to cover the vessel and leave the wound open for four to six days for delayed closure. Anticoagulants should not be necessary when an intima-to-intima repair is performed properly without constriction of the lumen and establishing a good blood flow. Antibiotics, however, are protective to such repairs performed in the presence of open wounds.

FIG. 6

Although some constriction of lumen exists at this popliteal artery anastomosis site, the distal circulation is excellent. Such constriction may result from excess tension held on the arterial suture during repair.

Patency of the major vascular channel is not always necessary for limb survival but it is desirable. A surgeon untrained in vascular surgery or lacking proper instruments and faced with an injury to a large artery may be forced to ligate the vessel. Other situations which may demand ligation of the artery are those in which other priority surgery may prolong the operating time excessively or when a number of patients are awaiting lifesaving surgery. Ligation may be indicated for an injured vessel running through a large avulsed soft-tissue wound where no tissue remains to cover the vessel. Following ligation of a major artery, irreversible changes must be expected in a percentage of the cases. The incidence of amputation varies according to the vessel involved and according to the severity of the injury involving the artery. For this reason various percentages are quoted in the literature [17,25]. Even though the limb may survive ligation of its major vascular channel, the possibility of gaining a good functional limb after ligation of its artery is limited. The prognosis for limb

survival following ligation of its major artery is better in the upper limb than in the lower. Should ligation of a major artery become necessary, this alone is not an indication for ligation of the concomitant vein [20].

Treatment of the patient with an acute pulsating hematoma varies with the situation, the condition of the patient, the availability of proper instruments, and the ability of the surgeon. The majority of patients with a pulsating hematoma will have a palpable pulse distal to the hematoma and a viable extremity. If proper wound care is given without dislodging the clot, most can be treated conservatively until the pulsating hematoma develops into an arteriovenous fistula or false aneurysm at which time definitive surgery may be done. In a percentage of patients with pulsating hematoma complications of infection, expansion with pressure on vital structures, or hemorrhage will develop and will require emergency surgery as reported by Russell [19]. For hemorrhage in the presence of infection, ligation of the involved artery is indicated. Ideally, if a surgeon trained in vascular repair is available with necessary supplies and equipment, the vascular injury producing a pulsating hematoma should be repaired immediately as any other acute vascular injury. However, if the surgeon, unfamiliar in dealing with these injuries, opens such a lesion without proper vascular control, he may lose a life or be forced to ligate the vessels and possibly lose a limb. While the limb loss is not as great if the artery feeding a pulsating hematoma is ligated some days after injury as it is from ligation of an acutely damaged artery, a degree of functional impairment of the limb still occurs. The artery usually can be ligated safely some months later after the pulsating hematoma develops into a false aneurysm or an arteriovenous fistula, but arterial insufficiency will occur in a high percentage of patients. This was demonstrated in the treatment of 814 arteriovenous fistulae and false aneurysms reported by Elkin and Shumacker from World War II [25]. The author and his associates [9] treated 215 arteriovenous fistulae and false aneurysms of which thirty lesions of major vessels were treated by obliterative surgery months after injury. Of the patients so treated, arterial insufficiency developed in 30 per cent. A five-year follow-up study of this group showed that arterial insufficiency had increased to 50 per cent in the group undergoing obliterative surgery for major vessel lesions.

THE FRACTURE WITH ARTERIAL INJURY

Fracture associated with disruption of the main arterial channel is one of the more serious complications encountered by the orthopaedist. It is difficult to treat one without treating both. Without restoration of the blood supply, ischaemic gangrene frequently will result. Even if the extremity retains its viability with its major blood supply ligated, bone repair is slower and the end result may be less than desirable. The presence of a fracture is no contra-indication to repairing the injured vessel. One late follow-up study of acute vascular injuries showed no increased incidence of thrombosis in arteries repaired in the presence of fractures [12].

The complications begin immediately. With vascular disruption at the level of the fracture site, the application of the desired pressure dressing for control of hemorrhage is more difficult. Any angulation or motion of the fractured bones may increase bleeding. Stabilization by any form of temporary splinting and traction, as with the Thomas splint, results in an already ischaemic foot being elevated with some traction device applied. This necessary evil, in addition to the existing spasm and the possibility of some degree of shock in the patient, further adds to the ischaemia. If a pulsating hematoma exists at the fracture site in a closed soft-tissue wound, this may interfere with the treatment of the fracture; therefore, repair or ligation of the vessel becomes necessary. The open soft-tissue wound with involvement of bone and artery poses a different problem. The wound must be debrided and at that time the artery is identified, bleeding is controlled, and the lesion is repaired. Arterial repair in the presence

of a complete fracture usually is facilitated by the overriding of the ends of the bone, making it possible to appose the ends of the vessel more easily. While vessels may be repaired in this manner, it must be realized that the resulting excess vessel cannot be excised and the surgeon then expect to reduce the fracture. If more than two centimeters of vessel is destroyed, a graft may be indicated. After vascular repair is performed, the fracture should be reduced manually with the vessel visualized to be sure that it is not under undue tension, separated, or that spasm does not result. Soft tissue should be placed between the vessel and fracture site for nourishment to the vessel and to prevent compression and incorporation into scar tissue. Precautions as to vessel length also must be taken during repairs near fractures about joints. After the repair is performed with the joint flexed, the joint should be extended with the vascular repair under vision to be sure adequate vessel length exists.

After vascular repair and wound débridement, the method of fixation of the fracture is the choice of the orthopaedist. The author has seen complications of vascular repair occur because of inadequate and excess traction for the fracture.

The utilization of a cast is undesirable for extremities which have been ischaemic. There is danger of pressure to the extremity. Ischaemic extremities often tend to swell after their blood supply is returned. Irreversible changes may develop in muscle in tight compartments when hidden by a cast. An improperly sutured vessel may leak and produce hidden hemorrhage or swelling. Failure or thrombosis of the arterial repair is more likely to be overlooked in a cast. Certainly, if a cast must be used and bivalved for safety of the arterial repair, then it loses much of its usefulness for treating the fracture. One limb was lost following vascular repair, done by the author, when the fracture slipped and compressed the repaired vessel.

Traction also offers disadvantages. The extremity in traction is elevated. It is desirable to have the extremity with newly established blood supply near heart level. The fixation of traction or a cast encourages arterial and venous thrombosis. Late hemorrhage has been observed to result from partial separation of a popliteal artery anastomosis in the presence of a compound fracture under traction. Ligation of the artery, indicated because of some bone infection, did not cause loss of the leg but resulted in functional arterial insufficiency.

Orthopaedic injuries admittedly complicate the repair of vascular injuries. It is difficult in many fractures and dislocations to determine whether or not absence of a pulse results because of compression by bone fragments, thrombosis, spasm, or a severed artery. The presence of a hematoma suggests tear in the artery but may result from widespread destruction of soft tissue and collateral vessels. The prognosis of such injuries in the past has been poor for extremity and sometimes for life.

Now that reconstitution of arterial channels is practical, we should emphasize the restoration of vessel continuity.

SUMMARY

With the trend toward reconstructive vascular surgery, this paper discusses the practicability of blood-vessel repairs in the presence of orthopaedic injuries. The incidence of vascular injuries in the presence of fractures is noted as varying from 10 per cent in civilian injuries to 56 per cent in one group of battlefield injuries. The complications of vascular injuries are presented and their prevention discussed. Operative care of acute vascular injuries and pulsating hematomata should be reconstructive rather than obliterative. It is pointed out that there are still indications for ligation of major vessels. While ligation of an artery feeding a pulsating hematoma is safer than ligation of an acutely injured artery, a high degree of functional vascular insufficiency may result. Care of the injured vessel in the presence of fracture is discussed stressing reconstructive vascular surgery.

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Patellectomy

Repair of the Extensor Mechanism *

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The indications for patellectomy are well recognized, and in recent years attention has been focused on surgical technique. Although surgical excision is a frequent procedure, no specific technique has become accepted as a method of choice. In 1937, Brooke encouraged excision of the patella, stating that it was an enlarged sesamoid which had negligible importance in the function of the knee. This was followed by a number of articles concerned with the pros and cons of patellectomy. Orthopaedic surgeons, such as Dobbie and Ryerson, Soto-Hall, and O'Donoghue and Hays, favored excision of the pathologically altered patella. Haxton, Alameda, Feddis, and Hull and DePalma, felt that the patella was necessary for full functional extension of the knee and preferred to retain it, if possible. It was thought also that excision of the patella resulted in a cosmetic defect and led to loss of protection to the knee joint. It must be emphasized that complete patellectomy should be done only when definitely indicated. It is a major procedure and should be considered as such.

Fifty years ago Murphy described a procedure (Fig. 1) in which he used a flap of the quadriceps tendon and muscle to reinforce the defect left by removal of the patella. Other methods have been reported which are variations of this principle. In 1950 Schopp and Fellhauser described a technique in which they prepared a tongue-like flap of the quadriceps tendon and a similar smaller flap of the patellar ligament for reinforcement. Miyakawa, in 1956, described a method of turning down a tongue from a portion of the quadriceps tendon and suturing it to the patellar ligament. In 1949, independently, the senior author initiated a similar procedure, termed the *inverted V-plasty*. We feel that this is a simple procedure which may be used in virtually all patients in whom patellectomy is indicated. It provides a strong closure and requires a short convalescent period with good functional and cosmetic results.

TECHNIQUE

A median parapatellar incision is used to expose the patella, the quadriceps tendon, and the proximal portion of the patellar ligament. The proximal arm of the incision extends about three inches above the patella and the distal arm to the tibial tuberosity. The fascia overlying the patella is incised vertically, and the patella is removed by sharp dissection. This permits salvage of the fascia which may later be used as a reinforcing structure. If the patella is fractured the lateral extensor mechanism is frequently torn, as is the synovial membrane of the knee joint. The patella must be removed piecemeal, the joint inspected, and the repair begun. The lateral structures, in the event of a tear, are repaired first. Attention is now directed to the quadriceps tendon which is exposed for two and one-half inches proximally (Fig. 2). An inverted V is incised through about two-thirds of the thickness of the tendon. In the event that the tendon is thin, the entire thickness may be used. The base is one-fourth of an inch above the defect left by removal of the patella, and the apex extends approximately two inches above the base. The apex and V are freed

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and reflected distally while the base remains attached. Two corner reinforcing sutures are taken in the lateral angles of the base to prevent stripping. The V is then folded downward over the defect left by removal of the patella. The apex should slightly overlap the patellar ligament. The V flap is inserted into the patellar ligament and is held by heavy mattress sutures under moderate tension. The sides of the flap are sutured to the edges of the defect in the anterior capsule. The fascia previously removed from the anterior surface of the patella is closed over the flap. The raw area created by lifting the flap may be partially closed by interrupted sutures in the quadriceps tendon. Partial flexion of the knee may be carried out to test the strength of the repair. Normal quadriceps tension is restored and a smooth surface fits against the femur. The reflected flap gives a fullness to the anterior surface of the knee that superficially resembles a patella. The knee is immobilized in a plaster cast for three weeks. Quadriceps-setting exercises are begun immediately, and the patient is permitted

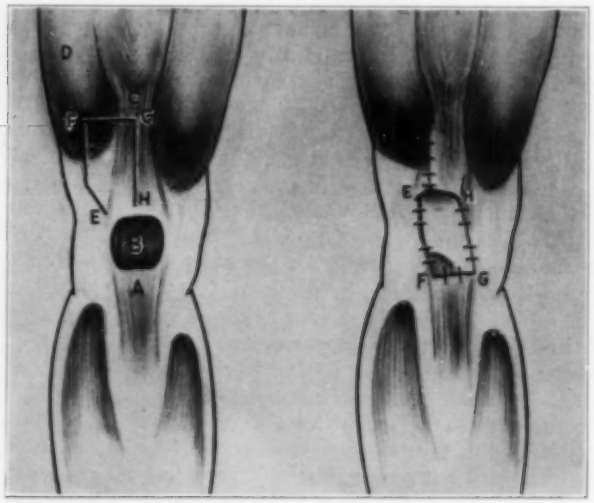

FIG. 1

Murphy's technique: *A*, patellar ligament; *B*, defect left by excision of the patella; *C*, quadriceps tendon; *D*, vastus lateralis; *E*, *F*, *G*, *H*, flap fashioned from quadriceps mechanism.

to walk with support in two to four days. Immobilization is removed three weeks after the operation and full weight-bearing without support is encouraged. Physical therapy is then directed at strengthening the knee in extension and securing maximum flexion. Return to normal activities varies but most patients are quite active in six to eight weeks postoperatively.

DISCUSSION

A statistical survey requires at least a minimal number of cases, and oftentimes no one surgeon can accumulate a series sufficiently large to determine accurately the true merits of a procedure. We agree with Thompson and Epstein's remarks that surgeons with an understanding of the reactions of the joint to trauma may arrive at a correct conclusion before a significant statistical comparison can be made.

We have evaluated the final results in forty patients with patellectomies; four of these were bilateral. Although the number is insufficient to establish statistical evidence of value, general trends are apparent. These operations have been done since 1949 by the Staff of the McBride Clinic. Thus, there has been

an opportunity to study several types of repair as done by six orthopaedic surgeons. These included:

1. End-to-end approximation of the quadriceps tendon to the patellar ligament;

2. Simple excision of the patella and suture of the fascia to close the defect;

3. V-plasty, as previously described.

The average period of observation of patients in whom other than the V-plasty operation was done was fourteen months. Of these, the shortest included in the series was one month; the longest follow-up was six years. Patients in whom the V-plasty operation was done were observed for an average of twenty-five months. The longest follow-up was eight years, while the shortest was six weeks.

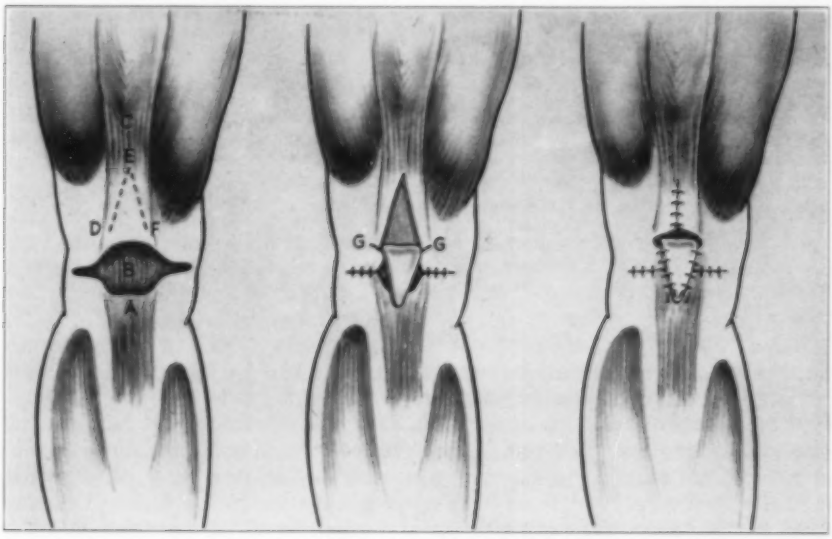

FIG. 2

Author's technique: *A*, patellar ligament; *B*, defect left by excision of the patella; *C*, quadriceps tendon; *D*, *E*, *F*, flap fashioned from quadriceps tendon; *G*, angle sutures.

Chondromalacia of the patella, which was associated in many cases with degenerative arthritis of the knee joint, and fractures of the patella were the two most common conditions for which patellectomy was done in this series. Other indications were rheumatoid arthritis, chondroma of the distal portion of the femur, villonodular synovitis, osteochondritis dissecans of the patella, and recurrent dislocation of the patella. As is noted, there is a diversity of diagnoses, and, of course, one would be faced with the usual difficulty in comparing results. The final results of the patellectomy depended as much on the patient's age, his activity, muscle tone, and joint disease as the surgical procedure used. All cases were evaluated as to the final function of the knee, the following criteria being used:

Excellent: extension to 180 degrees with resistance, flexion normal, no pain;

Good: extension to 180 degrees actively, flexion slightly limited, slight pain;

Fair: extension to 170 degrees actively, flexion moderately limited, moderate pain with fatigability;

Poor: extension less than 170 degrees actively, marked limitation of flexion, marked pain.

Study of the material obtained indicates that simple closure was the most commonly used procedure in chondromalacia and yielded predominantly fair

and poor results. Although less cases are evaluated in comparison, the V-plasty yielded no poor results; the results were predominantly good. Fractures of the patella were seen frequently in patients having severe and multiple injuries, and it is noted that the end-to-end procedure was done as frequently as the V-plasty. Again, with V-plasty there were no poor results. Instead, the results were predominantly good and fair.

Three of the remaining ten cases in this series were discarded because of the incomplete follow-up. In the seven included the results were as follows: A simple closure was done on a rheumatoid knee with a poor result. Two knees, with recurrent dislocation of the patella, were repaired with end-to-end closure with good results, as was one knee with villonodular synovitis in which the result was poor. The final three knees, one with osteochondritis dissecans of the patella, one with chondroma of the femoral condyle, and one with rheumatoid arthritis, were treated by means of V-plasty. The results were excellent, fair, and poor, respectively.

TABLE I

Total	Diagnosis	Type of Surgery	No.	Excellent	Good	Fair	Poor
22	Chondromalacia	Simple closure	13	2	3	5	3
		End-to-end	3		1	1	1
		V-plasty	6	1	4	1	
12	Fracture	End-to-end	6	2	1	2	1
		V-plasty	6	2	2	2	

SUMMARY

Forty patellectomies were done for various reasons by six orthopaedic surgeons during an eight-year period. Study of these suggests that the V-plasty for reinforcement of the quadriceps mechanism consistently yielded good results in all types of cases. The study also revealed that in most instances simple excision of the patella yielded very good results. The possibility of reserving the inverted V-plasty for those patients in whom damage has occurred to the extensor mechanism that cannot be easily repaired by simpler methods may be considered. However, the inverted V-plasty is not a difficult procedure and may be used in virtually all patients in whom patellectomy is indicated. It provides a strong closure, requires a short convalescent period, and results in a pleasing cosmetic appearance with good function.

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(Discussion on page 1418)

Arthrogryposis Multiplex Congenita

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An affliction of infants characterized by multiple rigid joint deformities, which were present at birth, was first described by Otto in 1841. The name *arthrogryposis*, meaning curved joint, was first used to describe this condition by Rosencranz, in 1905, and was later used by Stern and by Lewin, each of whom described a number of similar cases. Although other names have been proposed, which are perhaps more accurately descriptive of the nature of the disease, there is a certain charm in the word *arthrogryposis* which seems to ensure its continued use. The condition is a congenital disorder involving the extremities; frequently all four extremities are involved, sometimes only one or two. The condition is characterized by an appearance of marked wasting, due to diminished muscle substance, increased fibrous tissue about the joints, disturbance of joint mobility, and characteristic deformity. The changes are not confined to the muscles and joints, but may involve the skin and subcutaneous tissues. There is evidence suggesting that the central nervous system is affected[3, 5, 7, 11]. Bone itself seems to escape change except for secondary influences of the deformities and the forces of faulty weight-bearing. The joints in this condition are unique in that despite the rigidity, which is felt at the limits of motion, there is, in most cases, mobility of at least a few degrees which is quite free and painless. This motion may be entirely passive, there being little or no muscle present to activate the part.

The nature of the affliction is not well understood. The thin limbs were at first described as atrophic in the belief that the muscles wasted because of the stiff fibrotic joints. Later, it was suggested that amyoplasia was the basic condition with fibrosis of the joints occurring because of lack of intra-uterine activity[1, 14]. Some authors blamed abnormal intra-uterine compression of the foetus for these changes, while others considered the condition to be hereditary. Virus infection of the foetus *in utero* was suspected as a cause of this condition since it had been shown that other congenital anomalies were due to this cause. Another theory was suggested by the superficial similarity of these deformed joints to those afflicted with arthritis. It was believed that some sort of intra-uterine periarthritis might have produced the changes. Paralysis of the embryonic muscle, due to anomaly or lack of development of the embryonic nervous system, seemed to some investigators to be the best explanation for the lack of muscle substance and power[3, 5, 7]. The variety of theories explaining this disorder is easier to understand when one considers the great variety of clinical pictures arthrogryposis presents. One infant may appear to have paralysis with great muscle loss and joints with a wide range of passive motion. Another infant may have all four extremities in rigid extension, with the joints covered by smooth skin completely lacking skin creases; a third infant may have the extremities in flexion with webs of folded, smooth skin stretched across the angle of the flexion deformities. Still another infant may have tight club feet or dysplasia of the hips; in some, a mild deformity may be seen in which only one limb is moderately involved. A number of investigators based their conclusions on only a few patients, and it is easy to understand how false conclusions could arise from inadequate clinical material.

Other disagreements are frequent in the literature. The clinical observations of some include a high percentage of mentally deficient patients. Other investigators find these children quite normal mentally. A few authors imply that this is a progressive disease and compare it with progressive disorders of the central nerv-

ous system, such as those that occur in postnatal life, or they compare the condition with progressive muscular dystrophy [5,7,10]. This suggests an unfavorable prognosis which our observations show is not applicable to this condition. The name *amyoplasia congenita* is in wide use among pathologists to designate this condition [1,5,14]. Middleton, who made an extensive investigation of fetal musculature, prefers the term *myodystrophia foetalis deformans*. Until there is some general agreement as to the etiology and nature of this disease, there seems to be no advantage in changing its name.

This study is based upon forty patients who were examined and treated and upon whom close follow-up studies were possible. During a period of thirty-one years at the Shriners' Hospital for Crippled Children in Chicago, sixty-eight patients with this condition have been treated. It was felt that, with the advantage of having careful histories, good records, and good photographs of such a large number of patients, certain conclusions might be drawn which would be of some value in understanding the disorder. Of special importance are the long-term studies of twelve adult patients followed since infancy.

TABLE I

HEREDITY

Family History of Forty Patients

Congenital Anomaly	Immediate Family	Distant Relatives
Club-foot		2
Metatarsus varus	1	1
Dislocated hip		1
Arthrogryposis		
Heart anomaly	1	
Leg-length discrepancy		1
Deformed ear	1	
Deaf-mutism		1

Heredity

The theory that arthrogryposis is caused by a chromosomal defect has been an attractive one. Careful inquiry into the family histories of our patients disclosed very few congenital anomalies, and no instance of deformity which might be diagnosed as arthrogryposis. Hillman and Johnson have reported two instances of a typical arthrogrypotic patient having an identical twin who was unaffected. Our series includes two additional sets of twins in each of which one twin is normal and one has arthrogryposis. This seems to refute completely the theory that the disease is hereditary; it also casts doubt on the importance of other intra-uterine influences which could hardly affect one identical twin without some effect upon the other. We have not seen or heard of two members of one family with evidence of arthrogryposis.

Gestation Period

The mothers of our patients were questioned carefully about their health during pregnancy, their exposure to infection, and their awareness of fetal movement. They were asked to compare this particular pregnancy with previous or subsequent ones. Only one mother reported any significant illness (German measles in her second month of pregnancy) and another reported exposure to what was thought to be German measles. However, in general, the histories of their pregnancies seemed free of any unusual complications. That nearly all of these mothers felt the fetal activity between the fourth and fifth month of pregnancy and recalled no significant quietness of the foetus later on in pregnancy is surprising, especially

in view of contrary reports in the literature. We cannot depend upon diminished fetal activity to predict the birth of an arthrogrypotic baby.

Delivery

Most of our patients were born after full-term pregnancies which terminated with labor of average duration. In a very high percentage (36 per cent) of the patients, birth was by breech presentation and in three, by footling presentation. It is believed that this is the result of the deformity which obviously could prevent normal mechanics of birth. It is not likely that this malposition has anything to do with the development of the deformity. No significant postpartum complications appear to follow the delivery of babies with this condition.

TABLE II

PREGNANCY AND BIRTH—HISTORY OF FORTY CASES

Complications of pregnancy		7
German measles (second month)	1	
Exposure to virus disease	1	
Glycosuria	1	
Premature rupture of membranes	2	
Bleeding in third trimester	2	
Premature births		5
Normal fetal activity		31
Abnormal fetal activity		9
Excessive activity	3	
Diminished activity	6	
Throughout pregnancy	5	
Last weeks of pregnancy	1	
Labor		
Within normal limits		37
Abnormal		3
Precipitate birth	1	
Prolonged, difficult labor (One requiring Caesarean section)	2	
Presentation (Information in twenty-eight cases)		
Cephalic	15	
Breech	10	
Footling	3	
Neonatal complications		
Cyanosis		4
Protracted period	2	
Brief period	2	
Fractures at birth		2
Weak baby		3
Feeding problems (Both palate abnormalities)		2

Infancy

This disorder is most striking during infancy. At birth the baby is often so startling in appearance that the family is not permitted to see him, and many of these mothers were told that the baby was a hopeless cripple. One mother stated that her son had been "left on the windowsill by the hospital people for six hours in the hope that he wouldn't live." The marked lack of muscle substance, the rigidity, the unusual positions of the limbs, and the smooth uncreased skin enclosing the joints like sausage skin are characteristic. The extremely tight equinovarus deformities, or the typical narrow, adducted, internally rotated shoulders, and the deformed hands create a most depressing picture. A poor prognosis has been stressed by most writers. Stern, in 1923, said: ". . . the chances for making them self supporting are, indeed, very small." Despite their condition, these infants seem to have a normal zest for life. They take their feedings well and seem to resist disease as sturdily as normal children. Their deformed joints, which strongly re-

semble deforming arthritis, are not painful, and their skin tolerates corrective manipulation and casts very well.

Mental Status

From the literature one might get the impression that the incidence of mental deficiency is quite high in patients with arthrogryposis [7,13,16]. At the Shriners' Hospital in Chicago only two of the forty patients in this series were considered below normal in intelligence. One of these patients had cerebral palsy also, and we felt the mental deficiency was related to this condition. Despite the mechanical difficulties these patients have in writing and in other aspects of schoolwork (two of our patients write by holding the pencil in their teeth), nearly all of our older patients have finished four years of high school, and some have completed college. One patient, a doctor of philosophy in nuclear physics, is a member of the faculty of one of our finest universities. The hobbies of the children and adolescents, and the occupations of our adult patients indicate a rather high degree of intelligence. Certainly the stigma of deficient mentality must not be added to the burdens of these unfortunate people.

Pathology

There is general agreement among investigators concerning the tissue changes which occur in this disease, but there is a wide variety of opinions in the interpretation of the facts. Autopsy material is not abundant, for these patients are not numerous and their health is usually good. Death usually occurs from another unrelated disease which may have affected some of the material examined. Most material has come from frequent opportunities to obtain tissue at the time of surgery. This type of tissue, however, has not given much information about the nature of the disease. Moore, in 1936, examined peripheral-nerve tissue from a child with arthrogryposis and found areas of fibrous infiltration of nerve bundles similar to that which he described in cases of neurofibromatosis and in the nerves supplying the area of congenital pseudarthrosis of the tibia. Gilmour, Brandt, Adams, Denny-Brown, and Pearson, and Kanof have described the spinal cord of arthrogrypotic patients. There seems to be no doubt that the number of anterior horn cells is diminished, while the other parts of the cord are unchanged. Gross dissection shows that muscles vary greatly in their appearance. One muscle may be of normal size and color while an adjacent muscle may be small and pale, or absent. Microscopically, there is abnormal variation in the size of the muscle fibers, most of them being smaller than normal. Some of the muscle fibers appear greatly hypertrophied and may lie next to fibers of small diameter. Fat infiltration is often seen, but degeneration of muscle fibers has not been a prominent finding. Some investigators conclude from this material that the disorder is a primary defect of the central nervous system, similar to amyotonia congenita or Werdnig-Hoffman's muscular atrophy. Other investigators consider the condition congenital amyoplasia or myodysplasia. While a discussion of the evidence found in the literature would be stimulating, the study of our cases has not contributed to this phase of the subject. In our observations of these patients during surgery, we have always been impressed by increased fibrosis around the joints and the lack of loose areolar tissue under the skin. From these observations, we feel that these changes are more than the result of prolonged disuse as has been claimed. We believe this is a part of the pathological process.

Extensive laboratory examinations of arthrogrypotic patients have been undertaken at several institutions [7]. It has been found that routine tests are all within normal limits. Recently it was shown that the electrophoretic pattern of the serum proteins may be altered in arthrogrypotic patients with a definite elevation of the alpha$_2$ globulin fraction and a slight lowering of the gamma globulin value. In this small series of patients, a consistent increase in the creatine excretion was found. In reading these reports, however, one gets the impression that the patients did not

TABLE III

DIAGNOSTIC FINDINGS IN FORTY PATIENTS

Multiple contractures	38
Contracture of one hand only (One foot pronated also)	1
Contractures of feet only	1
Total	40
Extremities involved	
All four	20
Both lower extremities	11
Both lower and one upper	7
Both upper extremities	1
One lower and one upper	1
Total	40

have typical cases of arthrogryposis since neurological findings were rather prominent. All the patients had a definite increase in the deep reflexes and seemed spastic.

Diagnosis

Laboratory assistance is not necessary to diagnose arthrogryposis correctly. The findings described should be sufficient to identify the clinical picture. The reflexes of our arthrogrypotic patients depended upon the muscle development of the part being tested. If the muscles producing the reflexes are not involved, the reflexes are normal. If the muscles are markedly diminished in size, fibrotic, or absent, there will be little or no reflex response. There are other conditions which

TABLE IV

DEFORMITIES OF THE LOWER EXTREMITY

(Thirty-nine of Forty Patients)

Feet (thirty-seven of forty patients had abnormalities)	
Equinovarus	
Bilateral	28
Unilateral	2
Equinovalgus	
Bilateral	2
Unilateral	1
Rocker-bottom deformity	
Bilateral	2
Calcaneovalgus	
Bilateral	1
Equinus deformity	
Unilateral	1
Hips (twenty-seven of forty patients had abnormalities)	
Dislocation	
Bilateral	9
Unilateral	6
Flexion deformity	15
Extension deformity	1
Flexion, abduction, external rotation	9
Adduction	1
Internal rotation	1
Knees (thirty-three of forty patients had abnormalities)	
Bilateral abnormality	32
Unilateral abnormality	1
Flexion deformity	25
Extension deformity	8

TABLE V

DEFORMITIES OF THE UPPER EXTREMITIES

(Twenty-nine of Forty Patients)

Abnormality		No. of Patients
Shoulders: Bilateral deformity		15
Elbows (involved patients)		18
Flexion deformity		
Bilateral	4	
Unilateral	3	
Extension deformity		
Bilateral	11	
		23
Wrists (involved patients)		
Flexion deformity		
Bilateral	15	
Unilateral	1	
Extension deformity		
Bilateral	2	
Pronation contracture	4	
Supination contracture	1	
		21
Hands (involved patients)		
Flexion of fingers	19	
Extension of fingers	2	
(ulnar deviation of fingers: 1)		
Thumb adduction-flexion deformity	10	

may, in one respect or another, superficially resemble arthrogryposis. We have examined patients with multiple congenital anomalies who had one or two joints almost typical of this condition, but the appearance of other areas of the body did not conform. In some patients with spina bifida, there are joint and limb deformities accompanied by a lack of flexion creases. The equinovarus deformity of the foot and the appearance of the knee joints resemble arthrogryposis. The rest of the clinical picture, however, enables one to diagnose easily the condition. None of the

TABLE VI

ABNORMALITIES OF THE SKIN

(Forty Patients)

Abnormality	No. of Patients
Absence of normal skin creases	40
Port-wine facial stains	7
Dimpling of skin at joints	13
Definite webbing	21
Contracture of facial muscles	2

In one patient not included in this series, facial contractures constitute a major part of the deformity and disability.

neurological disorders with which arthrogryposis is compared in the literature has ever caused us difficulty diagnostically.

Treatment

Most of the deformities caused by arthrogryposis are difficult to correct. The unyielding fibrous thickening around the joints or the tense skin may prevent successful manipulation. Patient efforts to stretch these structures slowly with casts will generally be rewarding. The lack of muscles may render a joint useless even

though a considerable range of free motion is present. Open surgical release of fibrous contractures may fail because the vessels and nerves cannot tolerate the tension necessary for adequate correction of the deformity, or the inelastic skin may not be sufficiently mobile to permit closure of the operative wound after the contracture has been released. Such discouraging factors should not deter the surgeon from making an earnest attempt at correction. One must obtain stability and good weight-bearing alignment in the lower extremities by one means or another, and radical measures may be required. Congenital defects seemingly unrelated to arthrogryposis often occur coincidentally. Certain others are common enough to be considered a part of the disorder. The treatment of these is included here.

Club-foot: Talipes equinovarus is the usual deformity. The feet are often very rigid and usually lack development of the heel. Treatment by a series of well

FIG. 1

FIG. 2

Fig. 1: M. T. Photograph shows typical upper-extremity deformity. The patient has severely diminished muscle volume.

Fig. 2: O. H. Equinovarus deformity, a typical case in an untreated older child. Note the absence of flexion creases at the knees.

padded corrective casts should be started as early as possible; if the surgeon is careful and patient, good results can be achieved. Corrective treatment should be carried out in the usual sequence: correcting talipes varus of the fore part of the foot, swinging the foot into a valgus position, and then into dorsiflexion. If a tight posterior ligament and Achilles tendon prevent release of the heel, and rocker-bottom deformity is feared, early open surgical release must be done, although the results of the procedure in these feet may be somewhat disappointing. There is a strong tendency for arthrogrypotic club-foot to relapse, but the usual management of recurrent club-foot generally succeeds in maintaining reasonably good position and function until the foot has developed and grown sufficiently to allow more radical surgery. We do not hesitate to perform medial soft-tissue release or other soft-tissue surgery in the younger child when it is evident that we will be unsuccessful with corrective or wedging casts. Dorsolateral tarsal bone-wedge resections, triple arthrodesis, and other major bone operations should be delayed as long as possible because of the destructive effect these operations have on grow-

ing bone, since these feet appear small and stunted. Most of these patients eventually have some sort of stabilizing operation, for as they get older the feet become rigid and only correction of the bones themselves will help. The persistence of troublesome equinus deformity after these procedures has required, in some cases, wedge osteotomies in the distal tibial metaphysis to place the foot in the proper weight-bearing position. In some adolescent patients, spontaneous bony ankylosis of the ankle joints has occurred; when the position of the foot has been good, satisfactory function has resulted. The surgeon should never be satisfied with anything but a good position in these patients since, by osteotomy, he can place the foot in exactly the desired position. Astragalectomy, while not as frequently done as it once was, has given good results in an occasional unstable calcaneus deformity associated with arthrogryposis (Figs. 7-A through 7-E).

FIG. 3

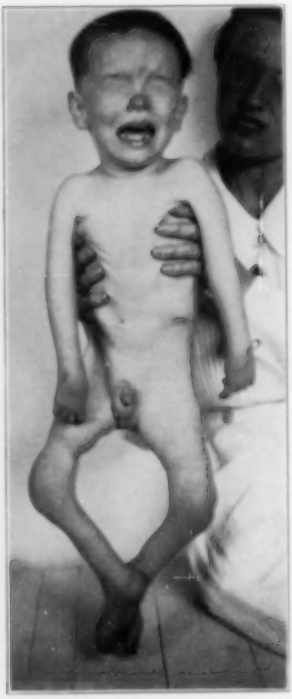

FIG. 4

Fig. 3: B. W. Knee contractures with bilateral dislocation of the patella.
Fig. 4: D. D. Photograph shows typical severe involvement of all extremities. Note marked lack of musculature, extensive skin changes, and multiple joint contractures. This patient is now an adult and wears toe-to-groin braces.

Dislocation of the hip: This is a common complication of arthrogryposis and the most difficult to correct. If the hips are rigid and flexed, it is doubtful if the dislocation can be reduced, and many surgeons do not make the attempt. Open surgical release of fibrous contractures must be performed if the flexion deformity cannot be released by traction or other simple methods. Even with an anterior dislocation of the hip, the patient can often walk moderately well; this type of dislocation is stable enough to tolerate weight-bearing and is not associated with serious lordosis. The range of severity is wide in dislocations of this type; however, some are sufficiently mobile to allow an atraumatic reduction by traction and gentle manipulation, or by open surgery. Abduction casts may then be applied as in the more usual treatment of congenital dislocation of the hip with some hope

of success. It seems that the surgeon should treat these hips conservatively whenever there is the slightest chance of success. Nothing is lost by trying, and often some advantage is gained. In some patients the deformity must be corrected or weight-bearing improved by subtrochanteric osteotomy. The problems must be studied individually since general rules of treatment will not apply to specific cases. The prospect for the achievement of normal function of the hip in these cases is poor.

Knee joints: The knee joint may be flexed with a moderately free range of passive motion but with very little muscle power to control it. The quadriceps may appear to be absent, and the patella difficult to palpate or absent. In many instances the knees will be in complete extension or hyperextension. Occasionally the joint will move in an abnormal plane, having free lateral motion but rigidity in normal directions of motion. When the disorder is extensive, restoration of a good knee joint is rarely possible. A weight-bearing position must be achieved by wedging casts, release of soft tissue, or by osteotomy. If there is insufficient muscle power for stability, toe-to-groin braces will be required. In one patient in whom knee motion was in a plane 90 degrees from the normal, capsulotomy completely encircling the joint enabled rotation of the tibia and resulted in improvement in function. Supracondylar osteotomy may be required for rotation or correction of rigid flexion deformities.

TABLE VII
ASSOCIATED DEFORMITIES

Deformity	No. of Patients
Temperomandibular joint contracture	1
Dislocated shoulder (bilateral)	1
Klippel-Feil syndrome	2
Syndactylism (toes)	1
Scoliosis (structural)	1
Spina bifida (occulta)	2
Sacral defects	1
Constriction bands	2
Coxa vara (unilateral)	1
Undescended testes	4
Synostosis, talus and calcaneus (bilateral)	1
Cerebral palsy	3
Funnel chest	1
Dislocated patella (one unilateral)	2
Palate defects	2
Absent lateral ray	1
Inguinal hernia (bilateral) and umbilical hernia	1

Shoulders: Defect in the shoulders is often caused by lack of musculature. Passive motion is usually present in sufficient amount to allow the upper extremities to reach functional positions. We have not found it feasible to attempt muscle transplantations around the shoulder to correct this lack. Extreme internal rotation may be relieved by rotation osteotomy if this is necessary for function.

Elbows: Rigidity in extension or in flexion is the most common problem. Arms in rigid extension are almost completely useless; however, the patient often can use them as crutches to push himself about the crib. To improve function of the upper extremities, it is necessary that at least one hand be able to reach the face. A flexed elbow can be achieved by capsulotomy. After capsulotomy, muscle control may be lacking and the child may have to press his arm against some object, such as his knee or the edge of a table, to bring his hand to his mouth. We have tried to transfer a functioning triceps tendon to the flexor aspect of the forearm in

FIG. 5-A

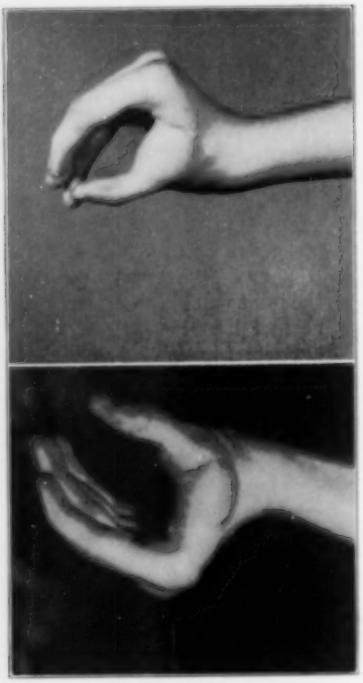

FIG. 5-B

Fig. 5-A: B. M. A typical deformity of the hand caused by arthrogryposis is seen.
Fig. 5-B: Webs were replaced by pedicle grafts, and the thumbs were fused in position of function; the patient is now able to typewrite at the rate of sixty words per minute.

FIG. 5-C

FIG. 5-D

Condition of the patient at age three years, following treatment of the soft tissues of the left foot.

FIG. 5-E

FIG. 5-F

Condition of the patient in 1952 at age fifteen.

order to create active flexion but have failed in all instances to accomplish this. Because of the inelastic skin, full-thickness skin grafts have been necessary in two patients to cover the exposed bone of the olecranon after the surgical procedure.

Wrists: Flexion deformity of the wrist is very common, and is often increased by the patient's habit of supporting his weight in bed on the backs of his hands. The hands, which are often seriously involved, have little chance of usefulness until the wrist is placed in a position of function. This may require fusion, and only careful study of the individual patient's hand will enable the surgeon to decide the position in which the wrist should be stabilized.

Hands: The smooth, tapered fingers of patients with arthrogryposis have been compared to bent wax candles. They have a restricted range of motion and are often moderately flexed. The thumb is often flexed across the palm, from which position it can be moved passively but not actively. A strong web of skin usually prevents abduction. By ordinary standards one would consider such hands almost useless; however, these individuals may accomplish remarkable things with them. By replacing the webs with full-thickness skin grafts and by holding the thumbs in functional position by metacarpophalangeal fusion, we have obtained useful hands. For example, one of our female patients now types sixty words a minute (Figs. 5-A and 5-B). A young man (Case D. D.) who cannot lace his shoes is able to make a living as a radio repairman.

PROGNOSIS

From our clinical study of this large series of patients with arthrogryposis, we have determined that this is not a progressive disease. We must add that there is little or no evidence of spontaneous improvement. As these patients become older and learn to use whatever motion and power they have, they may appear to improve; however, careful study will show that actual improvement in power and the range of motion has not been great. Effective treatment has enabled these patients to use their extremities to the best advantage. With improvement in use, there may be some increase in power and in the range of motion. There is a tendency for joints to change as the patient becomes older and heavier; the feet become more rigid as the patient approaches adulthood and bone fusion has occurred apparently as a secondary effect rather than through any change in the disease process itself. Other joints, such as dislocated hips, may change due to the additional weight of the patient. This is what one would expect; it would be surprising otherwise.

CASE REPORTS

CASE 1. M.W., a six-year-old white female was first seen at the Shriners' Hospital for Crippled Children in October 1929. Since birth she had been unable to straighten her knees or to bend her arms. She walked on her knees which were heavily calloused (Fig. 9-B). The family had no history of congenital anomalies or other significant disorders. One sister and seven brothers were living and well. The child appeared to be in good health.

Initial examination: At initial examination, there was no evidence of illness. The child showed about 80 degrees of passive motion in the knees, from 55 degrees to 135 degrees. Beyond these limits they could not be forced. The elbows had extension deformity with little motion, either active or passive. The wrists, fingers, and thumbs were moderately flexed, but the range of motion was not recorded.

Treatment: Treatment was directed to the problem of weight-bearing, and effort was made to place the legs and feet in weight-bearing position. This was accomplished by the use of wedging casts for the knees, and special corrective casts, relying on rubber-bands for their continuous corrective force, to improve the equinovarus deformities. These measures were successful in less than six months. Braces were required and were used for eight or ten years. The patient has since had bilateral supracondylar osteotomy, bilateral triple arthrodesis, and bilateral fusion of the fourth and fifth toes performed elsewhere.

Follow-up examination: At follow-up examination at age thirty (Figs. 9-C and 9-D), this unmarried woman was employed as a bookkeeper. She had completed high school and a fifteen-month course at a business college. She walked with somewhat of a waddle, not because of hip instability, but due to the weakness of the quadriceps, which made it difficult for her to "swing through" with the legs in walking. There was moderate recurvatum of the

FIG. 6-A

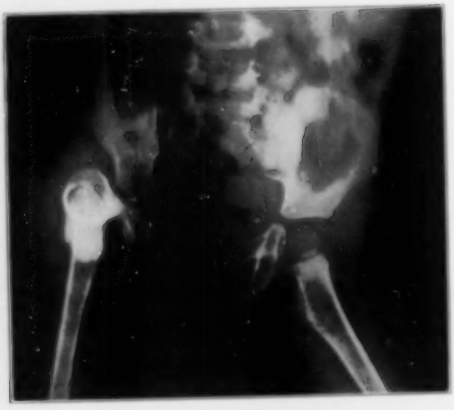

FIG. 6-B

Fig. 6-A: R. S. Roentgenogram shows dysplasia of the right hip with anterior dislocation. The contralateral hip, in abduction deformity, has a satisfactory acetabulum and normal development.

Fig. 6-B: Contrast arthrogram illustrates anteversion and hourglass capsule. The roentgenogram was made with the knee in the neutral position.

right knee. The patient preferred to use crutches for outdoor activity because of the security they afforded. The upper extremities showed evidence of considerable improvement. The shoulders were limited in abduction partly because of webbing of the skin in the axillae. The elbows had flexion to 75 degrees on the left and 90 degrees on the right. Extension to 180 degrees was present in both. The forearms, wrists, and hands were practically normal in function.

Result: This case illustrates a good result. The extensive contractures responded better than most deformities caused by arthrogryposis to the corrective forces of apparatus and the stretching effect of functional demands.

CASE 2. B.M., a white female was first seen in 1937 at the age of four months. Her mother stated the pregnancy had been normal except for diminished fetal movements, and birth occurred normally in the ninth month. It was noted that the child had deformities of all four extremities at the time of delivery. The hips and knees were in a flexed position with external rotation of both lower extremities. All of her fingers deviated ulnaward, and the thumbs were held contracted into the palm of each hand (Figs. 5-A through 5-D). A review of the patient's family history was unrevealing.

Initial examination: Initial examination revealed extremities with multiple contractures of the joints. The shoulders and elbows were normal, but the hands had fingers resembling bent wax candles with absence of flexion creases. The thumbs were held flexed and adducted, while the other fingers showed moderate stiffness and ulnar deviation.

Examination also revealed bilateral external rotation, flexion, and abduction of the hips, with marked limitation of motion. Dislocation of the left hip was found. Moderate range

FIG. 7-A

FIG. 7-B

C. S. Roentgenograms show severe anomalies of the feet. Note incidental Kohler's disease of the right foot.

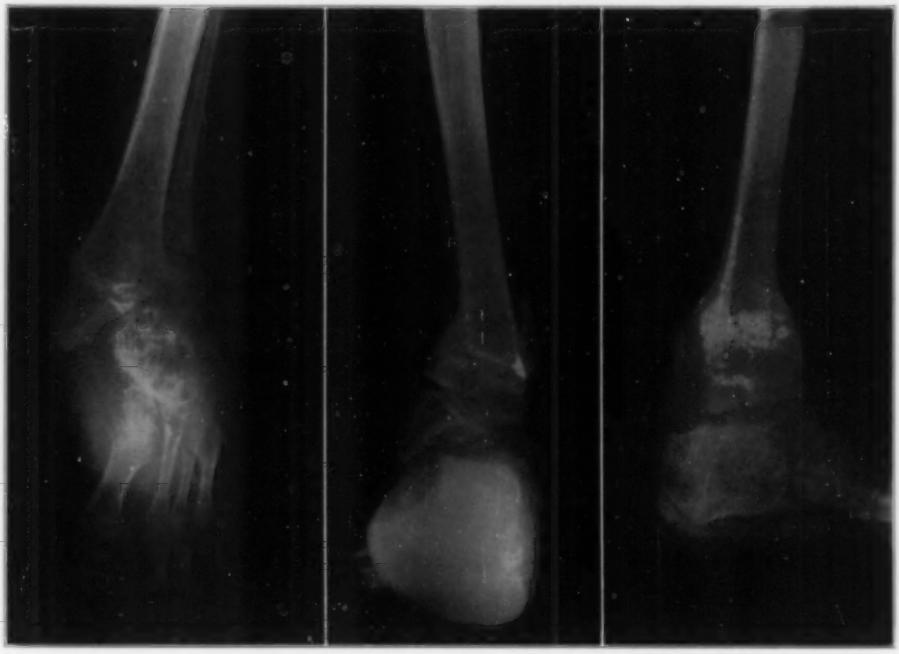

FIG. 7-C

Roentgenogram made of the left foot and ankle *(left)* after astragalectomy for calcaneovalgus deformity. There is severe deformity of the ankle mortise. The corrective effect of osteotomy of the distal portion of the tibia can be seen *(center* and *right)*.

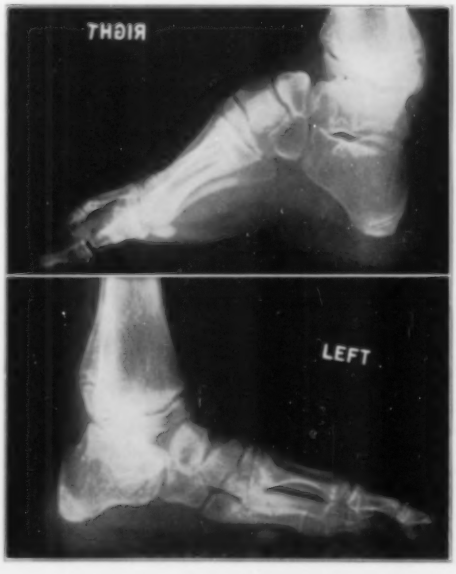

FIG. 7-D

FIG. 7-E

Roentgenographic appearance of both feet at last follow-up examination. In August 1955, multiple osteotomies of the metatarsus improved the deformity of the fore part of the left foot. The tibial osteotomy improved the weight-bearing position of the left ankle.

FIG. 8-A

FIG. 8-B

T. P. Roentgenograms showing bilateral equinovarus deformity in a man twenty-six years old after multiple stabilizing operations and spontaneous ankle fusions. The patient walked on the lateral side of the feet and wore shoes with elevated heels. He had essentially no motion in his feet or toes.

FIG. 8-C

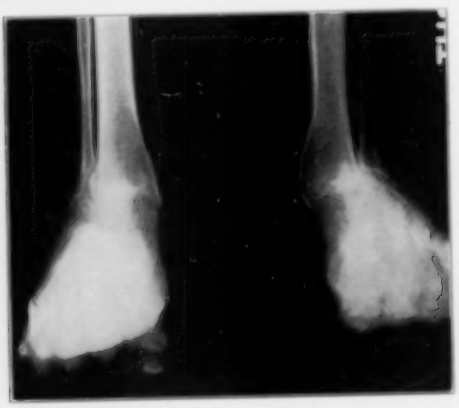

FIG. 8-D

Roentgenograms, made after generous removal of anterolateral wedges from the distal portion of both tibiae, show restoration of proper weight-bearing position. This man is a nuclear physicist at a well known university.

of knee motion, marked stiffness of the feet, left talipes equinovarus, and right talipes equinovalgus were noted.

Treatment: In September 1938, release of the left medial tarsal joint and plantar fasciotomy were performed. On March 12, 1938, partial tenotomy of the tendo achillis was done on the left. The results of these two procedures were good.

At the age of three and one-half years, in April 1940, a Z-plasty was performed on the web space between the thumb and index finger of the right hand, and the flexor pollicis longus tendon was lengthened.

In April 1940, the joint capsules of the right tarsus were incised, and the navicular was excised because of pronounced valgus deformity of the foot.

In March 1943, a wedge osteotomy was performed on the right foot because of marked valgus position, and was repeated in July 1945 because of recurrence of the deformity. Also, in July 1945, a full thickness skin graft was inserted into the first web space of the right

hand after the first metacarpal had been osteotomized to bring the thumb into full abduction and extension.

In October 1946, a left triple arthrodesis was done for recurrent equinovarus deformity. At the same time, a full-thickness skin graft was placed in the web space between the thumb and index finger of the left hand.

In April 1949, surgical arrest of the right distal femoral epiphysis and proximal tibial and fibular epiphyses was performed in an attempt to equalize two inches of leg-length discrepancy. Also in 1949, the dislocated metacarpophalangeal joint of each thumb was fused in a position of 45 degrees of flexion, and a pedicle graft was inserted bilaterally into the adjacent web space.

To improve stability of the left hip, a Schantz subtrochanteric osteotomy was performed in 1950, and in August 1951 a two-inch shortening of the right femur was performed with good results.

Follow-up examination: Follow-up examination at age nineteen revealed that the patient had finished high school, danced, enjoyed athletics, typed sixty words a minute, and was then a full-time employee in a large office. We feel her gait and general cosmetic result are good. No braces are needed, and she has had no further treatment since discharge (Figs. 5-E and 5-F).

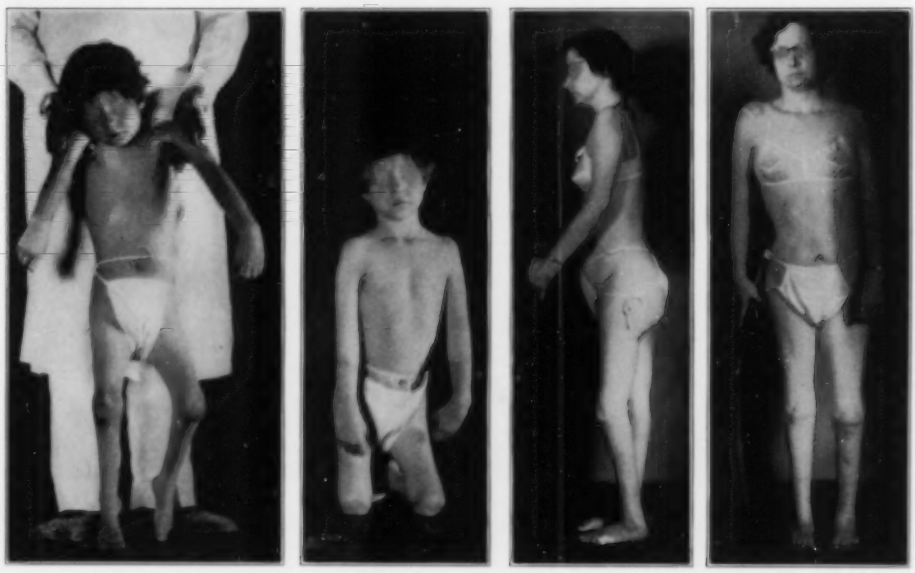

FIG. 9-A FIG. 9-B FIG. 9-C FIG. 9-D

Figs. 9-A and 9-B: M. W. Photographs showing the condition of the patient on admission; patient walked on her knees. Photographs show range of passive motion in the knees.

Figs. 9-C and 9-D: Photographs showing the patient at age thirty. She is relatively free of deformity but must be careful because of weak quadriceps muscles.

Examination of the trunk revealed a curvature of the spine toward the left with the apex at the tenth thoracic vertebra. The left leg was one inch shorter than the right.

The patient was able to use her hands quite well even though the range of motion in all fingers was diminished. Excellent pedicle grafts were present in the web spaces between the thumb and index finger bilaterally. There was a combined flexion contracture and ulnar deviation was present in the metacarpophalangeal joints of the other fingers; however, the patient could make a good fist bilaterally. The metacarpophalangeal joints of both thumbs were fused in 45 degrees of flexion and thumb motion was generally limited.

The patient had hip flexion to 65 degrees and abduction to 45 degrees bilaterally from a neutral position. All other hip motions were normal in the right hip. The left hip, however, could not be internally rotated, and adduction was not possible past 10 degrees. The Trendelenburg sign was positive on the left.

The feet were in good weight-bearing position with only slight varus of the toes of the left foot. The remainder of the left foot was in neutral position; she had 10 degrees of dorsiflexion and 30 degrees of active and passive plantar flexion. Moderate valgus deformity was still present in the right foot. Range of motion in the right foot was 35 degrees of plantar flexion from the neutral position; no dorsiflexion was possible.

Case 3. L.W., a six-year-old white female was first seen in July 1929 because of bilateral dislocation of the hip and equinovarus deformities of the feet. The feet had received surgical treatment at another Shriners' Hospital. The family history revealed nothing of significance. The birth history was incomplete, but the child was born with the legs crossed upon the abdomen.

Initial examination: At initial examination, the deformities of the feet appeared to be fairly well corrected, only adduction of the fore part of the foot and equinovarus deformity remained; however, the hips were dislocated posteriorly and produced the characteristic wide perineum and waddling gait (Figs. 10-A and 10-B).

Treatment: Bifurcation osteotomies of the hips, followed by casts and a period of training in walking was believed to have improved the condition of this child. Her condition was not originally diagnosed as arthrogryposis until the limitation of the knee motion and the characteristic appearance of the knees with their covering of smooth, uncreased skin, were noted. The child was followed in out-patient clinics and progress was satisfactory. After her discharge from Shriners' Hospital she was operated upon at another hospital and bilateral triple arthrodesis was performed.

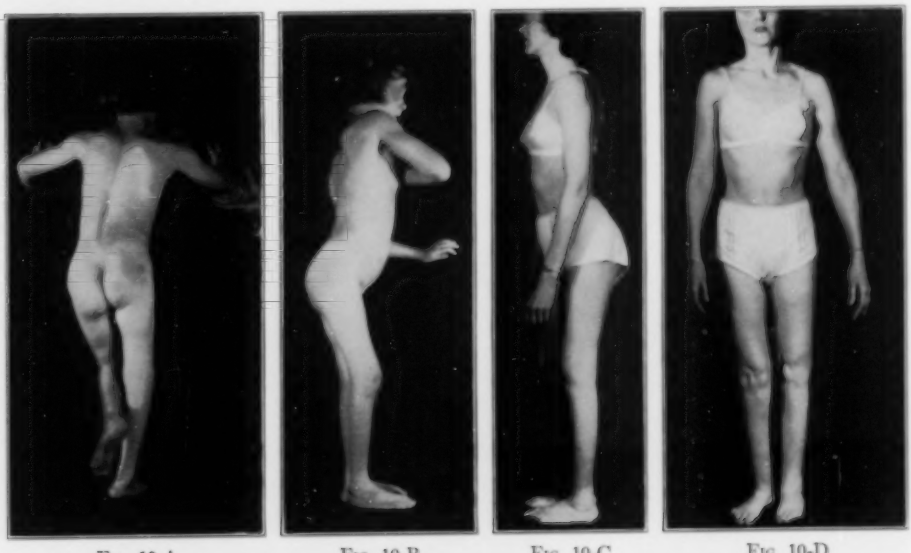

Fig. 10-A Fig. 10-B Fig. 10-C Fig. 10-D

Figs. 10-A and 10-B: L. W. Photograph made on admission of the patient. The feet had previously been operated upon. She has bilateral dislocation of the hip and mild involvement of her upper extremities.

Figs. 10-C and 10-D: Patient's condition at age thirty. Bilateral triple arthrodesis had been done; persistent dislocations of her hips are well tolerated.

Follow-up examination: At age thirty this patient was unmarried and employed as a secretary. She complained of fatigue in her hips with much stress especially when climbing stairs which was difficult for her. She had a waddling gait characteristic of the patient with a bilateral positive Trendelenburg sign. Abduction was possible to 25 degrees in both hips. She could flex her left hip from 180 degrees to 110 degrees, and her right hip from 180 degrees to 140 degrees. Bilaterally, knee flexion was possible to 90 degrees, but the left knee could not be extended beyond 170 degrees. Function of the ankles and feet was satisfactory despite external torsion of the right tibia.

Result: Treatment of the hips was, perhaps, a failure. It is not certain whether they are better than untreated hips of this type. Certainly correction of the feet was of great value.

Case 4. J.B., a white male, was first seen at Shriners' Hospital for Crippled Children on November 5, 1943, at the age of three. There was no significant family history. The history of pregnancy and birth was noncontributory, except for the fact that delivery was complicated by breech presentation. The neonatal and infancy periods were normal, and the child's development progressed satisfactorily.

At birth, flexion, external rotation, and abduction contractures of the hips were noted. Knee flexion contractures and bilateral talipes equinovarus were present. A slight flexion deformity of the left wrist was also noted. Multiple series of corrective casts were applied to the feet and knees with little permanent success.

Initial examination: At initial examination (Fig. 11-A), marked diminution of muscle mass throughout both legs, especially below the knees, was noted. Multiple contractures were present throughout the lower extremities. The passive range of motion in the legs was markedly limited and the involved joints also lacked flexion creases. The hands and fingers were normal but the left wrist showed a slight flexion deformity.

Treatment: The child was first treated with corrective casts for bilateral equinovarus deformity and knee flexion contractures. Braces were prescribed at the age of five and he was able to walk with the help of crutches. Bilateral hamstring tenotomy and bilateral posterior capsulotomy of the knees were performed at the age of six. In August 1948, he had bilateral lengthening of the tendo achillis and bilateral release of the soft tissues of the tarsal joints medially. Recurrence of the knee flexion contractures required wedging casts on several occa-

FIG. 11-A

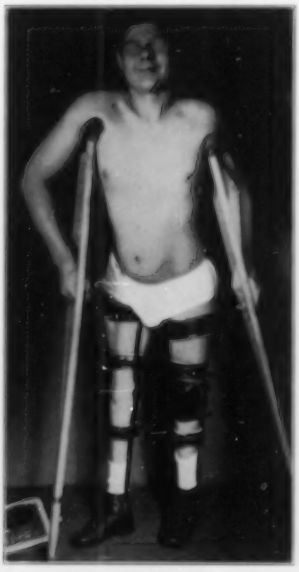

FIG. 11-B

Fig. 11-A: J. B. Photograph shows the condition of the patient at the time of admission with typical involvement of the lower extremities. The patient walked on his knees, but could run on his hands alone.

Fig. 11-B: Extensive surgery of the soft tissues and bone was required to correct the deformities. The patient has nearly no muscle power in the lower extremities.

sions. When the child was eleven years old, derotation osteotomies were performed on both femora to correct external rotation deformity. The following year the feet were stabilized with bilateral triple arthrodesis. In September 1954, at age fourteen, an osteotomy of the lower portion of the left femur corrected equinovalgus deformity. The patient was placed in toe-to-groin braces, and ambulation was satisfactory with the aid of crutches.

Follow-up examination: At follow-up examination, the patient, then seventeen years old, was in his third year of high school, and could walk well with bilateral toe-to-groin braces and crutches. He was interested in hunting and archery. Examination of his arms showed only mild limitation of extension of the left wrist. Examination of the lower extremities revealed normal hip motion in all directions except for marked limitation of flexion. The right hip could be flexed from 180 degrees to 120 degrees and the left hip from 180 degrees to 130 degrees. The knees showed passive motion from 170 degrees to 150 degrees bilaterally. Little or no quadriceps and hamstring power was present. Both feet were found fixed in a position of 20 degrees of equinus deformity and 30 degrees of varus contracture; they were not painful. The deformities have recurred since the permanent discharge of the patient at the age of fifteen. At that time the feet were in neutral position and the knees were straight. It is our belief that this patient's condition could be greatly improved by bilateral osteotomy of the distal portion of the tibia.

CASE 5. R.D., a white male, was examined in our clinic for the first time in 1942 at the age of four years. Review of his family history disclosed an older brother with a deformed external ear. The patient's mother stated that the pregnancy had been normal, except for premature

birth at seven and one-half months after conception. Birth, neonatal period, and infancy were normal.

After birth, both legs remained in flexion with the ankles crossed beneath the buttocks. Further inspection revealed bilateral talipes equinovarus and undescended left testis; the arms and trunk were normal.

Passive stretching of the contractures was performed by the family and constituted the only treatment of the patient until the age of four.

Initial examination: At initial examination (Figs. 12-A and 12-B), our physical findings consisted of the following: abduction, external rotation, and flexion deformities of both hips; bilateral knee flexion deformity in a position of slightly more than a right angle; bilateral talipes equinovarus deformity; decreased muscle volume and diminution of flexion creases of both lower extremities; a moderate range of passive motion in the knees and hips; and an undescended left testis.

Treatment: The equinovarus deformities were treated with a series of corrective casts and manipulations under anaesthesia with good results. Posterior soft-tissue release performed on the right knee helped the patient's condition.

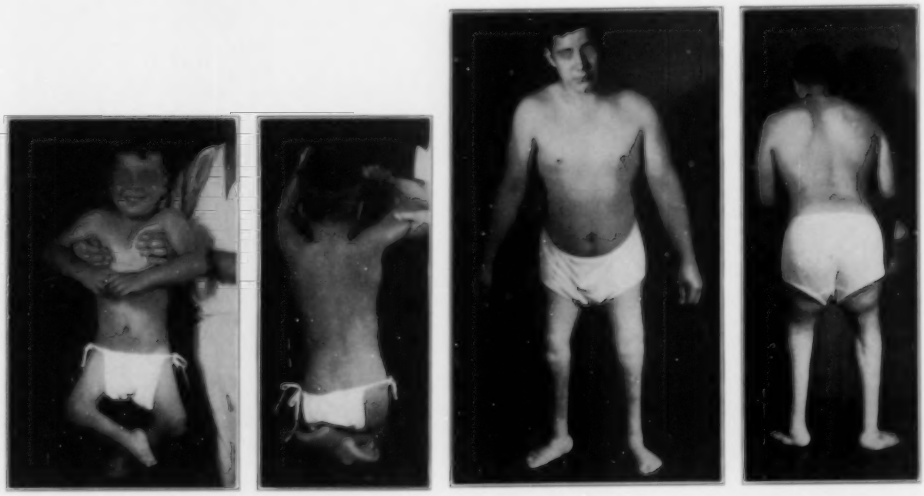

FIG. 12-A FIG. 12-B FIG. 12-C FIG. 12-D

Figs. 12-A and 12-B: R. D. Photographs show the condition of the patient at time of admission and the range of passive motion of the knees.

Figs. 12-C and 12-D: Legs and feet have been placed in a functional weight-bearing position by soft-tissue release and wedging casts. The patient also had a tarsal wedge resection on the right and a triple arthrodesis on the left. He wears braces part of the time.

At age seven, due to recurrence of deformities, bilateral soft-tissue release was performed medially, and two years later, the flexion deformities of the knees were severe enough to warrant posterior soft-tissue release.

In 1949, at the age of eleven, toe-to-groin wedging casts were employed to correct recurrent knee flexion contractures. In 1951, when this boy was thirteen years old, a tarsal wedge resection on the left and a triple arthrodesis on the right were performed for recurrent foot deformities.

Follow-up examination: When examined at age eighteen (Figs. 12-C and 12-D) we found the patient quite acceptable cosmetically; both the patient and his parents felt that past treatment had greatly improved the condition of the lower extremities. He had finished the eighth grade but did not attend high school.

Examination of the lower extremities revealed that both hips had 20 degrees of flexion, and 10 degrees of external rotation contracture. Each hip had 20 degrees of abduction and adduction, and flexion from 160 degrees to 120 degrees. All hip muscles were quite strong, and the Trendelenburg sign was negative bilaterally. Marked tapering of the lower extremities from the upper part of the thighs downward was noted.

No active knee extension was found, but knee flexor power was quite strong. Both knees had motion from 160 degrees to 150 degrees. The feet were quite rigid and stiff; there was only 10 degrees of plantar flexion from a neutral position. They were placed well for weight-bearing, and were quite serviceable.

The patient's pronounced waddling gait was attributed to stiffness in his knees and feet, as well as to his wide stance. He is able to drive a tractor and do odd jobs. We feel that this patient's result is quite good.

RESULTS OF TREATMENT

The results that have been obtained in treatment of arthrogryposis have varied to a marked degree. The reasons for this are clear since the severity of the deformity varies greatly. Club-foot of a lesser degree of severity responds readily to simple conservative measures and, in such a foot, the tendency to recur may not be troublesome. However, another case of club-foot may be extremely tight and resistant to correction; in such instances, there is frequent tendency to relapse in

TABLE VIII-A

SURGICAL OPERATIONS FOR CORRECTION OF FOOT DEFORMITY
(Forty Patients)

Medial soft-tissue release	
Bilateral	7
Unilateral	5
Achilles-tendon lengthening	
Bilateral	11
Unilateral	2
Stabilizing operation	
Triple arthrodesis	
Bilateral	7
Unilateral	4
Tarsometatarsal arthrodesis	1
Astragalectomy	
Bilateral	3
Unilateral	1
Tarsal wedge	
Bilateral	5
Unilateral	4
Tendon Transfer	
Tibialis anterior	1
Peronaeus longus	1
Hallucis longus	1
Osteotomy of the distal portion of the tibia	
Bilateral	2
Unilateral	2
Osteotomy of the matatarsal	2
Osteotomy of the calcaneus	1

spite of all forms of management. We find patients with such cases of club-foot reaching adulthood with an extremely stiff, or even ankylosed, ankle and tarsus and usually with rigid equinus deformity despite their having had manipulation, casts, and surgical correction. We may generalize that the more rigid the deformity at the onset of treatment, the greater the tendency to relapse regardless of what treatment is selected.

Many arthrogrypotic deformities do not require treatment at all, and the final results may be entirely satisfactory. Certain deformities, however, usually require treatment. The most common of these is club-foot. This deformity will inevitably progress with increasing disability as growth and improper weight-bearing exert their effect; in addition, there is the natural tendency for contracture to occur in these cases. Treatment of severe arthrogrypotic club-foot, therefore, aims at preventing increased deformity but the final results may not be obtained until the patient is almost fully grown. If treatment has succeeded in preventing gross deformity from developing in the foot, it has been successful. If the final result is a short, rigid, painless foot in good weight-bearing position, we consider it a successful result despite the fact that another surgeon seeing such a foot for the first time might be more impressed with the limitation and deformity which still exist.

The patient with severe club-foot in our series usually finishes treatment with this type of short, stiff foot.

Astragalectomy gives better results in some types of feet than would have been obtained by fusion. This operation has the advantage of correcting calcaneus deformity and extreme equinovarus deformity. Astragalectomy can be performed earlier than triple arthrodesis; this is a definite advantage in certain resistant cases which might be very difficult to control by more conservative methods. In no patient who had astragalectomy performed for arthrogrypotic deformity has pain developed. Occasionally a stiff equinus deformity has developed requiring further operative correction as the patient approached adulthood. Marked rigidity may account for the failure of a painful joint to develop at the site of the excised astragalus.

TABLE VIII-B

SURGICAL OPERATIONS FOR CORRECTION OF JOINT DEFORMITY AND LIMB-LENGTH DISCREPANCY
(Forty Patients)

Knee	
Soft-tissue release	
Bilateral	6
Unilateral	6
Patellar transfer with capsulotomy	3
Z-plasty of skin	1
Transfer of semimembranosus to quadriceps femoris	2
Supracondylar femoral osteotomy	
Bilateral	3
Unilateral	3
Osteotomy of the proximal portion of the tibia	1
Hip	
Open reduction	2
Subtrochanteric osteotomy	4
Hand and Wrist	
Z-plasty of skin	3
Skin grafts	
Full thickness	4
Pedicle	2
Pronator teres transplantation	1
Flexor pollicis longus lengthening	1
Wrist fusion	5
Osteotomy of the distal portion of the forearm	2
Osteotomy of the first metacarpal	1
Arthrodesis of the first metacarpophalangeal joint	2
Elbow	
Capsulotomy	3
Skin grafts	2
Triceps transfer	2
Limb-Length Discrepancy	
Epiphyseal arrest (femur and tibia)	2
Shortening of the femur	1

The knee joint also requires treatment when it is badly deformed or definitely unstable. In some patients, instability and lack of muscle substance immediately indicate the necessity of using toe-to-groin braces. Capsulotomy, tenotomy, and sometimes osteotomy above or below the knee joint will be required to produce proper weight-bearing alignment for braces, and the result is considered satisfactory. In other patients in whom there seems to be adequate musculature for control of the joint, once the deformity has been relieved, it is sometimes necessary to transfer tendons or otherwise make the most efficient use of the muscle power that exists. A lower extremity of this type can usually be restored to satisfactory function without the use of braces. By satisfactory, in such a case, we mean that ade-

quate stability will exist for walking even though the range of motion may be no more than 20 or 30 degrees at the knee joint.

The end results of surgical treatment of the hips of arthrogrypotic patients are uncertain from a study of this series of patients. Extreme conservatism was the rule in the days before World War II. Then, nearly all dislocated hips were allowed to remain as they were, though a trial of traction in abduction apparatus was sometimes made in the milder, more mobile, cases. Results of this were usually disappointing. Fortunately, those hips usually became stable enough for a fairly good gait (often a waddle) which was only painful after prolonged walking or weight-bearing. Stiffness, which is such an obstruction to successful treatment, is actually beneficial in producing stability when treatment fails. Best results occur in anterior dislocations, for these are stable enough to allow satisfactory gait in the majority of cases.

When the hip is mobile enough to encourage undertaking active treatment, the results have been doubtful. In no case has a normally mobile, stable hip been obtained in a dislocated arthrogrypotic joint. The dislocation often recurs if reduction is accomplished by traction and manipulation. Open reduction has not been observed long enough in a sufficiently large number of patients to enable us to draw conclusions. At the present time it appears that recurrence will be frequent. If a few of these reductions succeed, the attempts will have been worthwhile. In the extremely stiff unyielding hip, it is obvious that treatment will fail. If patients with this type of dislocation have troublesome instability when they are older, subtrochanteric osteotomies will improve their gait.

Results of treatment of the upper extremities have been satisfactory where the indications for surgery have been clear. A hand rendered useless by contracture of the thumb across the palm can have good results from a carefully planned plastic release of the thumb web and, if muscle is absent, fusion of the unstable thumb joints.

Wrist-joint deformities have given good results with fusion operations, but care should be taken that the wrist, fused in a functional position, enables the patient to care for personal needs.

Elbow-extension deformities usually have an associated lack of muscle substance. Placing one elbow, perhaps the right, in about 90 degrees of flexion may be an improvement. Efforts to transfer the triceps to the lacertus fibrosus or other stable structures on the flexor side of the upper part of the forearm have failed. In two recent patients, in whom a good range of passive motion was present, the transfer of a portion of the pectoralis major to an insertion in the forearm has been encouraging. This procedure deserves further trial.

Surgical improvement of the shoulder is rarely advisable. In this series, no surgical procedure has been performed on the shoulders; however, in one patient a shoulder fusion, indicated because of dislocation of the shoulder, will be done when the patient reaches the age of twelve.

In general, it appears that results of surgery are less favorable in patients with arthrogryposis than for similar deformities in patients with other diseases. An operative failure should not discourage the surgeon from persisting in his efforts to correct a disabling problem, even when this requires repeating the same operation a number of times on the same extremity. One girl in this series had medial soft-tissue release of her foot performed three times before she reached an age when arthrodesis was permissible.

Since the presence of contractures or the lack of muscle substance in an extremity may not seriously disable the patient, the mere presence of abnormality is not an indication for radical treatment. Extremities that can be used satisfactorily do not get worse when untreated. They tend to get somewhat better with continued use.

Table IX lists the late results of treatment on twenty-three patients. These patients have been followed long enough so that the ultimate result is predictable.

TABLE IX

RESULTS IN TWENTY-THREE PATIENTS

Patient	Sex	Age at First Treatment	Age at Time of Writing (*Years*)	Extremities Involved	Deformity	Surgery	Final Result
E.H.	M	14 yrs.	16	Upper, bilaterally	Hands, wrists, severe, bilaterally; extension contracture, elbows; shoulder contracture, bilaterally	Capsulotomy, left elbow; muscle transfer, left elbow	Left elbow in position of function; 30 degrees passive motion; triceps transfer failed; good dexterity of hands; no serious disability
P.G.	F	6 yrs.	13	Lower, bilaterally; upper, right	Bilateral club-foot; extension contracture, knee	Manipulation and casts; Achilles-tendon lengthening, triple arthrodesis, and tendon transplantation of foot, bilaterally	Good gait but persistent 20-degree equinus deformity bilaterally; to have tibial osteotomies at age fifteen, little motion in ankles
R.D.	F	3 yrs.	9	Lower, bilaterally	Bilateral club-foot; flexion contracture, knee	Manipulation and casts; bilateral osteotomy of distal portion of tibia; wedging cast and capsulotomy of left knee	Mild flexion deformity of knee; slight equinus deformity, left; wears normal shoes
H.F.	F	8 yrs.	15	Upper and lower, bilaterally	Bilateral club-foot; flexion contracture, knees; wrists, severe, bilaterally; extension contracture, elbows; bilateral shoulder contracture	Manipulation and casts; left tarsal wedge; bilateral triple arthrodesis; knee wedging casts, bilaterally; bilateral wrist fusion; capsulotomy, right elbow	Bilateral elbow contracture, right 90 degrees, left 160 degrees; bilateral wrist fusion makes self-care a problem; walks satisfactorily in toe-to-groin braces
J.B.	M	3 yrs.	18	Upper and lower, bilaterally	Bilateral club-foot; flexion contracture, knees; bilateral contracture, hips; slight flexion deformity, left wrist	Manipulation and casts; Achilles-tendon lengthening, bilaterally; triple arthrodesis, capsulotomy, knee wedging cast, and hamstring tenotomy, bilaterally; bilateral osteotomy near knee; bilateral subtrochanteric osteotomy	Requires toe-to-groin braces; stiff; severe equinovarus deformity; ready for final corrective surgery
B.M.	F	4 mos.	19	Upper and lower, bilaterally	Bilateral club-foot; left hip dislocated; bilateral hip contractures; hands, severe contractures, bilaterally	Manipulation and casts; bilateral medial release; bilateral triple arthrodesis; left subtrochanteric osteotomy; bilateral plastic operation, hands; epiphyseal arrests, femoral shortening	Feet stiff but good function in walking; leg length equalized; gait good despite scoliosis; can type rapidly with deformed hands

D.D.	M	2 yrs.	17	Upper and lower, bilaterally	Bilateral club-foot; flexion contracture, knees; bilateral hip contracture; wrists, severe, bilaterally; extension contracture, elbows; bilateral shoulder contracture	Manipulation and casts; Achilles-tendon lengthening, bilaterally; bilateral astragalectomy; bilateral capsulotomy and wedging casts of knee, bilateral osteotomy near knee; left wrist fusion	Requires toe-to-groin braces; repairs radios with deformed hands; takes complete care of self; has good range of passive motion but no muscle power
W.G.	M	5 yrs.	13	Upper and lower, right	Right club-foot; right hand severe	Manipulation and casts; plastic operation of right hand	Function of right hand markedly improved; more treatment planned; foot deformity not severe
C.S.	M	7 yrs.	15	Lower, bilaterally	Bilateral club-foot	Manipulation and casts; right medial release; left astragalectomy; left metatarsal osteotomy; tendon transplanation of left foot; osteotomy of distal portion of left tibia: bilateral subtrochanteric osteotomy	Excellent function of persistently deformed feet
B.W.	F	1 mo.	11	Upper and lower, bilaterally	Bilateral club-foot; flexion contracture, knee; bilateral hip contracture; hands and wrists, severe, bilaterally; flexion contracture, elbows	Manipulation and casts, medial release and Achilles-tendon lengthening, bilaterally; right hamstring tenotomy	Good gait, knee extension good; severe rocker-bottom deformity on right, series of operations required for stabilization of feet
R.D.	M	4 yrs.	19	Lower, bilaterally	Bilateral club-foot; flexion contracture, knees	Manipulation and casts; bilateral medial release, left tarsal wedge; right triple arthrodesis; knee wedging cast, capsulotomy, and hamstring tenotomy, bilaterally	Uses toe-to-groin braces part-time; has waddling, but satisfactory, gait; feet stiff in good position; mild bilateral flexion deformity of hip and knee
B.W.	F	3 yrs.	9	Upper and lower, bilaterally	Bilateral club-foot; right knee contracture, bilateral shoulder contracture	Manipulation and casts; arthroplasty, right knee	Knees unstable in all directions; hyperextension with weight-bearing; right foot stiff; treatment continues
T.Z.	M	2 yrs.	10	Lower, bilaterally; right, upper	Bilateral club-foot; right wrist, severe; flexion contracture of elbows	Manipulation and casts; right medial release; Achilles-tendon lengthening, bilaterally; tendon transplantation, right foot	Results on feet good; right wrist and shoulder fusion required
L.B.	M	2 yrs.	9	Lower, bilaterally; left, upper	Bilateral club-foot; left wrist, severe	Manipulation and casts; Achilles-tendon lengthening, right; tarsal wedge and triple arthrodesis, bilaterally	Feet rigid and small but function good; wrist fusion required when older
O.H.	F	10 yrs.	41	Lower, bilaterally	Bilateral club-foot; bilateral knee contracture	Manipulation and casts; tarsal wedge and triple arthrodesis, bilaterally	Feet rigid and small with tendency toward varus deformity; difficult to fit shoes; patient walks well despite slight knee limitation

TABLE IX (Continued)

RESULTS IN TWENTY-THREE PATIENTS

Patient	Sex	Age at First Treatment	Age at Time of Writing (*Years*)	Extremities Involved	Deformity	Surgery	Final Results
L.W.	F	6 yrs.	35	Upper and lower, bilaterally	Bilateral club-foot; bilateral dislocation of the hip	Manipulation and casts; bilateral triple arthrodesis	Waddling gait, feet stiff in good weight-bearing position; satisfactory result
E.W.	F	3 yrs.	31	Upper and lower, bilaterally	Bilateral club-foot; extension contracture, knee; bilateral dislocation and contracture of the hip; wrists, severe, bilaterally; flexion contracture, elbows	Manipulation and casts; Achilles-tendon lengthening, tarsal wedge, and astragalectomy, bilaterally; bilateral subtrochanteric osteotomy	Feet rigid and short; waddling gait; limited knee motion; mild flexion deformity of elbows; obese
E.P.	F	4 yrs.	27	Lower, bilaterally	Right club-foot; knee flexion contracture	Manipulation and casts	Mild equinus deformity in left club-foot; mild knee-flexion deformity persists; right club-foot not severe
L.F.	M	6 yrs.	25	Upper and lower, bilaterally	Bilateral club-foot; wrists, severe, bilaterally; bilateral elbow contracture	Manipulation and casts; medial release and triple arthrodesis, bilaterally	Feet in good weight-bearing position not rigid; elbows moderately flexed; hands deformed but uses them for simple work; mentally deficient
A.L.	M	6 yrs.	28	Upper and lower, bilaterally	Bilateral club-foot; knee extension contracture; right hip dislocation, left hip contracture, bilateral shoulder contracture	Manipulation and casts; medial release and astragalectomy, bilaterally	Knees and elbows stiff; feet in rigid equinus deformity; needs distal tibial osteotomies, bilateral position Trendelenburg sign, but stable when standing in wide abduction
J.C.	F	5 mos.	26	Upper and lower, bilaterally	Bilateral club-foot; knee extension contracture; left hip dislocated; hands and wrists, severe, bilaterally	Manipulation and casts; bilateral triple arthrodesis; bilateral wrist fusion	Feet in stiff deformity; patient has cerebral palsy and is mentally deficient; poor balance and coordination; hand function improved by wrist fusion
M.W.	F	6 yrs.	34	Upper and lower, bilaterally	Bilateral club-foot; knee flexion contractures; elbow extension contracture	Manipulation and casts; bilateral triple arthrodesis; knee wedging casts and osteotomy near knee, bilaterally	Doing well as school teacher; no serious deformity, feet stiff in good weight-bearing position
J.R.	M	2 yrs.	15	Lower, bilaterally	Right club-foot; knee extension contractures; dislocation and contracture of the hips, bilaterally	Manipulation and casts; bilateral knee wedging casts; osteotomy near right knee; left subtrochanteric osteotomy	Right foot good; has stable gait with dislocated hips; knee deformity improved by osteotomy

Objective evaluation of the results of each of the many procedures which have been used in treating these patients is unsatisfactory. Satisfactory weight-bearing and locomotion should be obtainable in all patients with arthrogryposis where there is no complicating abnormality of the central nervous system.

CONCLUSIONS

1. The etiology and pathology of arthrogryposis are not well understood, and there is no general agreement concerning them. Until the true nature of the disorder is known there is little advantage is using other names for the condition.

2. The occurrence of the disease in one member of each of four sets of identical twins, two of which are in this series, seems to exclude hereditary factors as the cause, and to cast doubt on theories of intra-uterine mechanical, circulatory, or toxic causes. The negative family histories further tend to exclude the theory that heredity is a cause.

3. The primary pathological site may be either in the spinal cord or in the muscles. It is believed that the fibrosis around the joints and in the subcutaneous tissues is a part of the pathological process and not merely secondary to intra-uterine inactivity.

4. Mental deficiency is infrequent in patients with arthrogryposis. When present, it does not appear to be more than coincidental. It is not directly related to arthrogryposis.

5. Deformities are difficult to correct and to maintain in correction. Function may be poor because of stiffness or lack of muscle power even when the deformity has been overcome. Stiff joints must be placed in the position of function, and unstable limbs must be braced for weight-bearing. If these things are accomplished, results will be satisfactory.

6. Patients with arthrogryposis, even though severely handicapped, generally make a satisfactory adjustment and live successful lives. Severe pain is not often present despite the poor mechanics many of these people must endure.

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Early Juxtacortical Osteosarcoma

(Parosteal Osteoma)

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Since the recognition of so-called parosteal osteoma by Geschickter and Copeland in 1951 and, under the name of juxtacortical osteosarcoma, by Jaffe and Selin in 1952, two unanswered problems, the pathogenesis and early recognition of this tumor, have engaged our attention. It is the thesis of this paper that the entity arises frequently, if not uniformly, as an osteochondroma-like lesion, and that it can be segregated almost from its inception from the simple osteochondroma. The following case of sarcoma of the femur, which was originally diagnosed as a benign condition, stimulated interest in this neoplasm.

Case 159. A housewife, twenty-six years old, was admitted for treatment of a painless swelling which had been present for six months in the right thigh. Roentgenograms made February 19, 1947 (Fig. 1), showed a tumor, arising from the medial femoral cortex, which

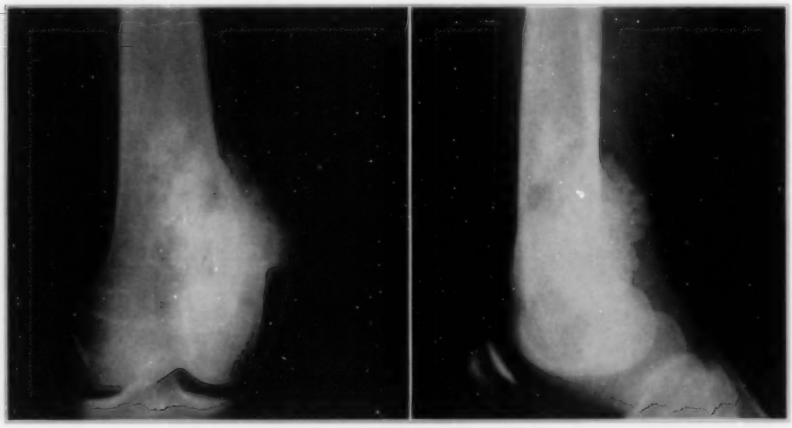

Fig. 1

Case 159. Roentgenograms showing a rounded, calcific, exostotic lesion suggestive of sessile osteochondroma.

was diagnosed as osteochondroma with the reservation that the suggestion of formation of spicules might indicate malignant change. On exploration a bone mass, approximately five by four centimeters, covered with smooth cartilage, was encountered. Proximally, the femoral cortex was thin, and when entered, numerous loculi of varying sizes, containing uniform soft, yellow, friable tissue, were found. In a few areas the tissue was almost white and was more firm. The entire medial femoral condyle and metaphysis three inches above it were honey-combed with these cysts. Incipient small cavities in the endosteal aspect of the cortex were noted after most of the contents of the marrow cavity were removed. No infiltration of soft tissue was evident. The surgeon thought the process benign. (Specimen submitted by Dr. Vinton Sneeden.)

In 1948, a recurrence was noted (Fig. 6), and the tumor again was excised. The bone defect made at the previous operation was found to be filled with soft, friable connective tissue. Attached to the cortex was a broad-based cauliflower-like growth four by five centimeters, which could be cut with a knife. It was well defined, but attached to the surrounding tissues. In March 1949, the tumor recurred and was excised. This tumor, a bony mass five

FIG. 2

Case 159. Photomicrograph (× 12) showing a lobe of the tumor—an osteochondroma-like lesion, with a cartilaginous cap and bone pedicle. Endochondral ossification is taking place. The cap is far thicker than that of a banal osteochondroma. In it, one can see a confused intermixture of areas of hyaline cartilage (seen best at the top and at the left), fibrocartilage, connective tissue, and osteoid (the darker-staining areas in the cartilaginous cap). Note the vascularity of the cap, not seen in the usual osteochondroma, and the marrow of the bone pedicle. The deeply shaded artefacts in the right half of the illustration are not visible to the naked eye.

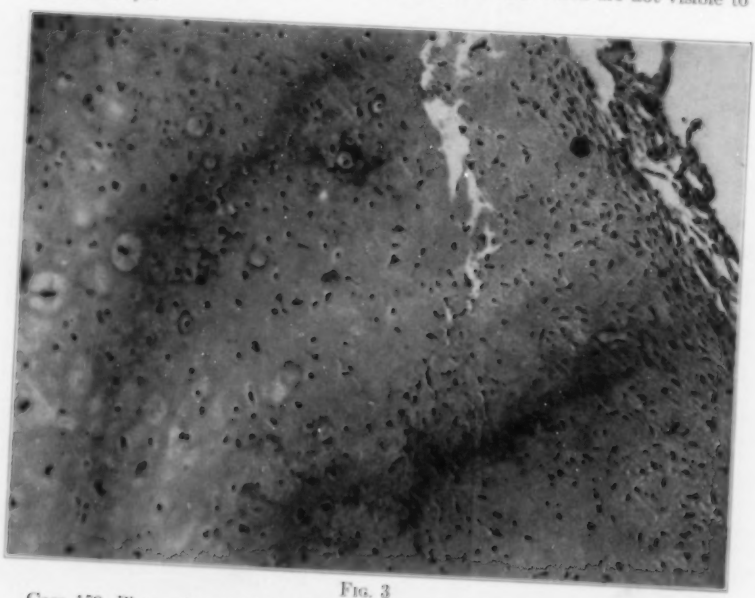

FIG. 3

Case 159. Photomicrograph (× 120) showing detail from Fig. 2. Note gradual transition from cartilage which is more or less of the hyaline type (seen at the bottom of the illustration), through fibrous cartilage to fibrous connective tissue under what should be the perichondrial surface. This may be considered dedifferentiation although the possibility of the reverse process cannot be excluded. The darker streaks have a pinkish coloration suggestive of osteoid.

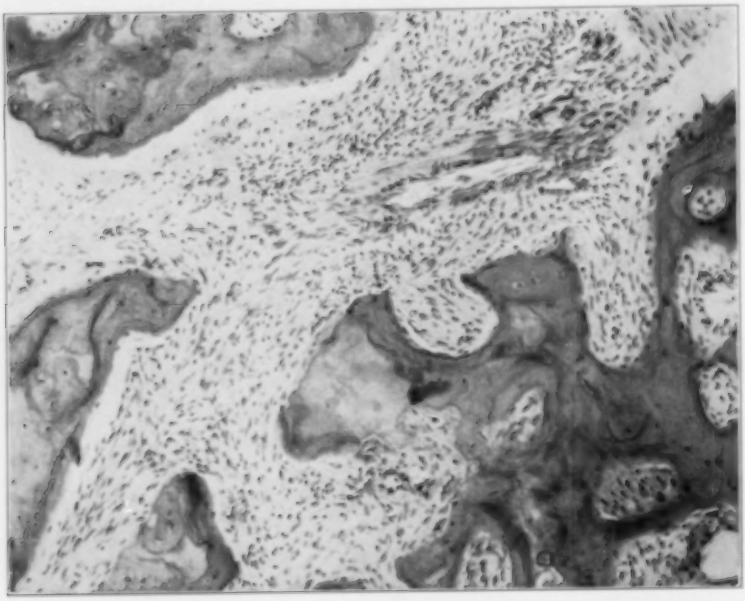

FIG. 4

Case 159. Photomicrograph (× 120) showing bone pedicle. Note the abundant fibrous connective-tissue marrow of the pedicle, which is not seen in simple osteochondroma.

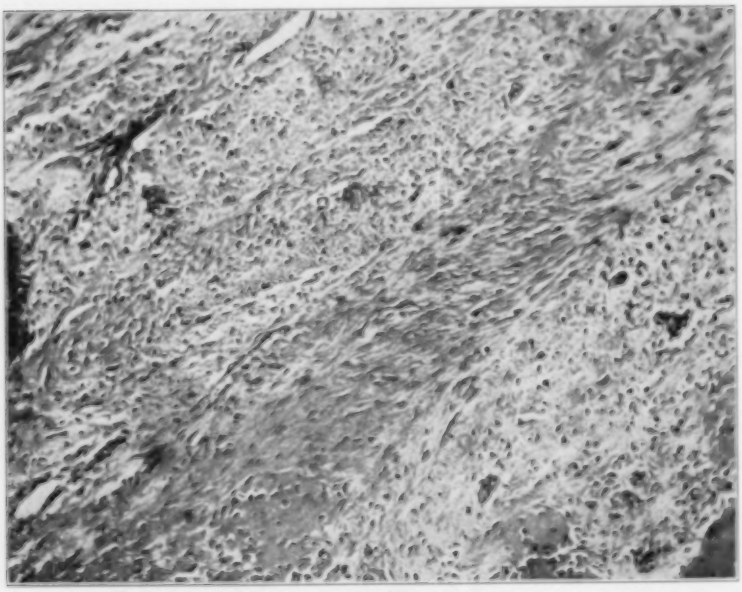

FIG. 5

Case 159. Photomicrograph (× 120) showing recurrent lesion. Note a more active fibrous connective-tissue proliferation in the tumor. The tumor, however, is not highly cellular, and the cells are not pleomorphic. Osteoid spicules can be perceived.

FIG. 6

Case 159. Roentgenogram showing recurrence with enhancement of intra-osseous and extra-osseous proliferation.

by three centimeters, was non-infiltrating, dense, and of irregular, granular appearance. A third recurrence, in November 1950, was biopsied, and when histological studies indicated increasing malignant change, amputation was performed. The amputation specimen showed a pale tumor tissue projecting abruptly from the cortex at the epiphyseal-metaphyseal junction, and elevated from the shaft for fifteen centimeters of its extent. It filled the marrow cavity of the metaphysis and the epiphysis and was poorly demarcated from normal bone and soft tissue.

Microscopic examination of sections of the original tumor showed a bone stalk with a cartilaginous cap beneath which there was endochondral ossification (Fig. 2). Some of the cartilage appeared hyaline, while other areas were fibrous, and some areas of apparent dedifferentiation of cartilage into spindle cells (Fig. 3) were evident. These were present superficially and within the depths of the lesion. Some metaplasia into osteoid was present with irregular orientation of the areas. The cells of the cartilage were variable, some being large and hyperchromatic. Double nuclei were fairly numerous. The intertrabecular marrow was fibrous and relatively cellular (Fig. 4). The architecture and cytology of the fibroblasts were not such as to suggest a malignant tumor.

The first recurrence yielded material which showed, at microscopic examination, a stalk of non-lamellar bone with connective-tissue marrow. The broad thick cap was composed of moderately cellular fibrous connective tissue with incipient pleomorphism, in which there were scattered areas of osteoid formation (Fig. 5).

The biopsy specimen from the second recurrence showed new bone-bearing masses of fibrous connective tissue. In parts of this the pleomorphism was more marked; cartilage, osteoid, and bone formation were present.

Microscopic sections of the third biopsy specimen showed interlacing bundles of dense connective tissue and cells, predominantly spindle-shaped (Fig. 7). Some areas showed osteoid while others showed new-bone formation. Nuclear variation was common in the fibrous connective-tissue elements, with an occasional cell showing two or more nuclei. Multinuclear giant cells were also seen. The biopsy specimen showed a progressive increase of the histological stigmata of malignancy.

At the Bone Tumor Registry, the diagnosis of parosteal osteoma was made on the basis of the atypical original lesion, long, slow progression, malignant, but not utterly unrestrained histological picture, and apparent absence of metastasis.

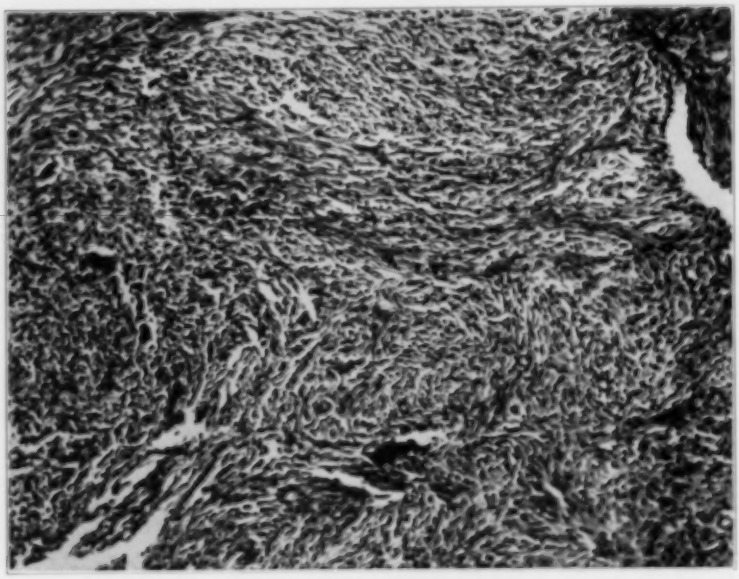

FIG. 7

Case 159. Microscopic section from the last operative specimen. Note the highly cellular and aggressive nature of the neoplasm, with tumor giant cells and nuclear pleomorphism. The lesion has assumed, by stages, the microscopic character of sarcoma.

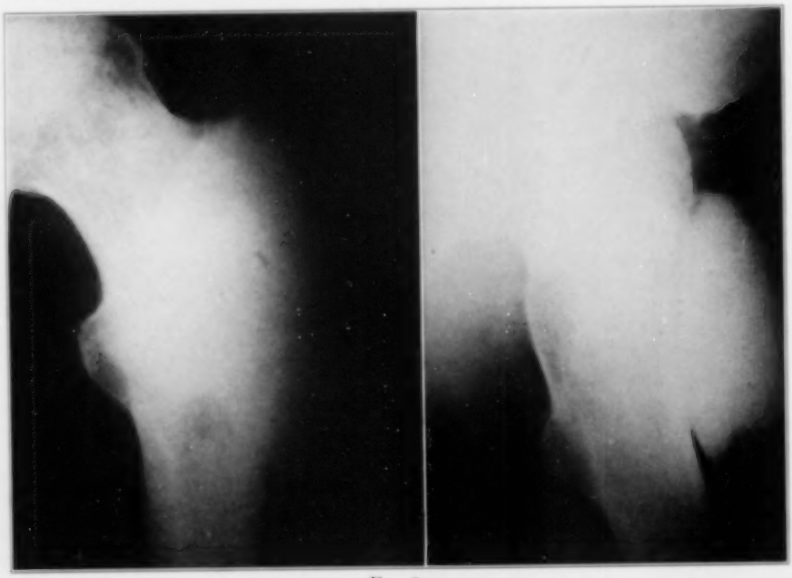

FIG. 8

Case 82. A superficially rounded, pedunculated lesion resembling a relatively sessile osteochondroma.

The material in the Bone Tumor Registry was then searched for analogous cases. Case 82 demonstrated an initial lesion of the general shape and appearance of an osteochondroma, in which, clinically and pathologically, malignant degeneration later developed in a manner similar to the previous case.

FIG. 9

Case 82. Photomicrograph (× 3) of tumor showing osteochondroma-like contour, with darkly staining bone pedicle and cap composed of fibrous connective tissue in which ossifying trabeculae can be distinctly seen.

CASE 82. In 1945, J. C. B., a woman, thirty-eight years old, noticed swelling and felt pain in the right hip. Roentgenograms revealed a tumor at the base of the neck of the femur (Fig. 8). This was resected and diagnosed as osteoid osteoma, arising in an osteochondroma. An ovoid mass six by six by 3.0 centimeters and another 4.5 by 3.0 by 1.7 centimeters each with an convex surface were found subperiosteally. Each had a flat attachment to the bone. The cut surface of the larger lesion showed primarily bony or firm yellow tissue interspersed with softer grey-brown areas. Cartilage was not recognized grossly. The smaller specimen was primarily bony. There was a recurrence in October 1946 at which time roentgenograms revealed incipient involvement of the intertrochanteric region and neck of the femur. A diagnosis of osteochondroma with malignant degeneration was made and roentgen therapy administered, a total of 7,500r being given in three approximately equal courses, five months and three months apart. The pain, limp, and swelling remained, however, and a biopsy in August 1947 led to a diagnosis of osteogenic sarcoma beginning in an osteochondroma. In January 1948, disarticulation of the hip was performed. The amputation specimen showed a nodular irregular tumor nine centimeters in diameter, which was bony in some areas and firm in others. The cut surface was predominantly bony with a few small hemorrhages and without cyst formation. The femoral neck and trochanters were involved extensively. No tumor was found other that that at the primary site, but, in December, lung metastases and local extension of the tumor became evident. The patient died in July 1949, primarily as a result of pulmonary metastasis. (Contributed by Dr. Warren C. Hunter.)

Microscopic section of the original specimen showed a base of lamellar bone upon which lay a mass of moderately cellular connective tissue with early pleomorphism. Osteoid and bone formation by metaplasia were present. No cartilage was seen. The architecture was somewhat irregular (Figs. 9 and 10).

Sections of the second specimen revealed trabeculae of bone with relatively acellular stroma. There was a moderate amount of new-bone formation and osteoid, and a few osteoclasts were seen. No highly cellular areas were present.

The amputation specimen revealed, microscopically, many spindle cells growing wildly. The tissue showed variable vascularization. Obvious sinusoids, in which cells lay in atypical mass arrangement and in which invasion was evident, could be seen. In other areas, the structure was more fibrous (Fig. 11). Collections of giant cells were present, many of them vacuolated. The more compact tissue predominated, and the cells showed irregularity in size and shape of nuclei and some hyperchromatism. Osteoclasts and the tumor type of giant cells were present, and osteoid predominated in a large part of the tumor.

The opinion of the pathologist who first examined the specimens that this tumor began as an osteochondroma must be noted, as must the marked increase

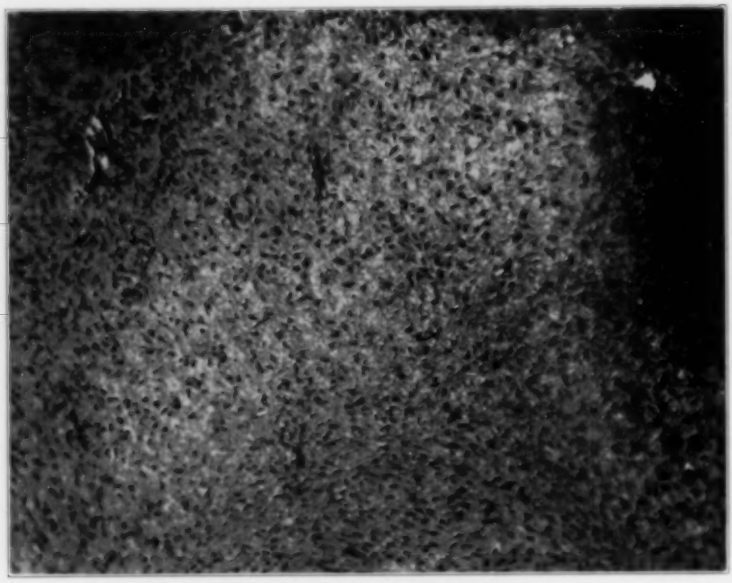

FIG. 10

Case 82. Photomicrograph (× 120) showing detail of fibrous connective tissue from Fig. 9. Note pleomorphism beginning, but lack of outspokenly malignant character of the neoplasm at this stage.

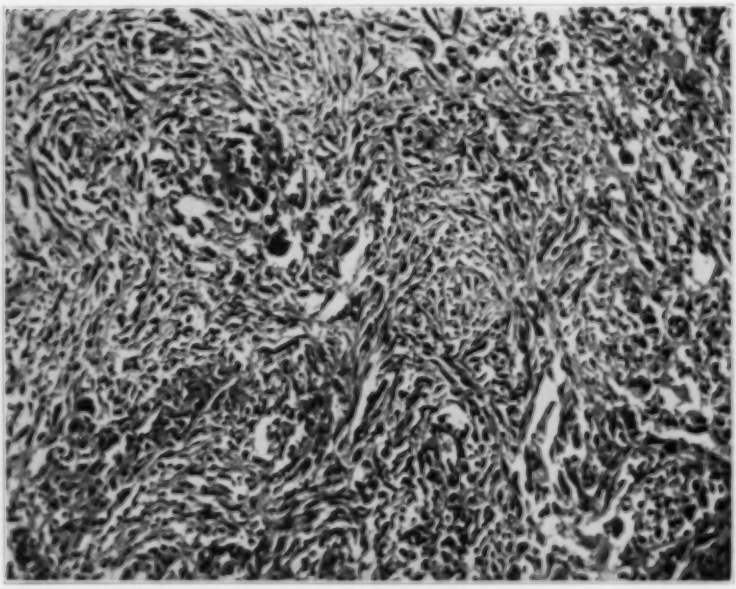

FIG. 11

Case 82. Photomicrograph (× 120) showing amputation specimen. Note the aggressive and disorderly architecture of the tumor. There is now marked cellular hyperchromatism and pleomorphism and numerous tumor giant cells. A sarcomatous appearance has developed.

FIG. 12

FIG. 13

Fig. 12: Case 277. Note that the border of the less calcified portion of the tumor shows the superficially rounded contour of a sessile osteochondroma. The roentgenogram has been timed to bring out this point, otherwise considerably more intra-osseous involvement would be evident.

Fig. 13: Case 277. Photomicrograph (× 36) of section of tumor. This too is predominantly composed of fibrous connective tissue, but with numerous foci of ossification.

in malignancy as manifested both clinically and by histological criteria (Figs. 10 and 11).

The question now arises whether or not the entity of juxtacortical osteosarcoma, so-called, arises in all or most cases from a lesion such as the one described. The following case shows that this may not be so, although in this disease entity, the initial roentgenographic examination often shows the gently curving, well-defined external surface that is characteristic of osteochondroma even if the stalk is lacking. This can be seen on several of the Geschickter and Copeland roentgenograms.

CASE 277. In February 1946, J. R. H., a boy, eighteen years old, suffered apparently minor injury to his right knee. Thereafter recurrent injuries were followed by swelling first noted by the physician in November 1950. A non-tender bony swelling, two inches in diameter was palpated. This appeared on roentgenographic examination (Fig. 12) as a large bony mass attached to the femoral cortex. In February 1951 wedge biopsy was done. The tumor grossly appeared fibrous with cartilaginous consistency. The need for a larger sampling of the tumor led to re-exploration one month later, at which time the portion of the tumor protruding from the lateral epicondyle was removed. Greyish red tumor was found extending into the marrow cavity, and was curetted. The main tumor was hard, with smooth, lobulated surfaces, while in the marrow, the tumor was firm and greyish white with the consistency of cartilage. After microscopic examination, a diagnosis of parosteal osteoma was made and amputation recommended, since wide excision was deemed insufficient. In April 1951 a mid-thigh amputation was performed and follow-up in April 1955 disclosed no recurrence or metastasis (Fig. 14). (Submitted by Dr. Walter A. Haug.)

Microscopic section of the first biopsy specimen revealed conspicuous bone trabeculae, most of them viable, scattered at random. The edge of some were frayed and surrounded by osteoclasts. In the more cellular portions of the stroma, there were spindle cells radiating in various directions, but pleomorphism and mitotic activity were not observed (Fig. 13).

A report from the Armed Forces Institute of Pathology stated that the microscopic pattern was that of myositis ossificans, with the disturbance in the

FIG. 14

FIG. 15

Fig. 14: Case 277. Photograph of amputation specimen.
Fig. 15: Case 482. Roentgenogram showing osteochondroma-like tumor of phalanx.

underlying bone, suggesting the possibility of parosteal osteoma. More extensive sampling was suggested. The second biopsy showed that the tumor, which was not encapsulated, contained similar material at its periphery and in the marrow cavity. There were many bone trabeculae embedded in relatively well differentiated fibrous tissue. Osteoid tissue and scattered multinuclear giant cells, many resembling osteoclasts, were present. Many of the trabeculae were lined with osteoblasts. The soft-tissue portions showed fairly uniform nuclear structure without any evidence of mitotic activity. Cytological study showed that this material was benign, but that it did not have normal bone architecture and should not have been present in areas peripheral to the cortex and in the marrow cavity.

This deviation was the reason for a diagnosis of parosteal osteoma. It is to be noted that osteochondroma was not suggested as the lesion of origin in this case, although, in the initial biopsy specimen, there was some suggestion of lobulation of the outer portion (Fig. 13).

The concept that a normal sequence of differentiation occurs in ordinary osteochondroma but that in parosteal osteoma an abnormal sequence consisting of apparent dedifferentiation and redifferentiation occurs was tested in another way. The abnormal sequence was sought in the cap of rapidly growing so-called osteochondromata. That such an abnormal sequence, consisting of the formation within the cap of cartilage and osteoid could be demonstrated, was evident in the next case.

CASE 482. L. H., a white male, forty years old, was seen with complaints of a mass on the lateral aspect of the little finger near the knuckle. There was a history of injury five years previously with no abnormality revealed in a roentgenogram. One year following the injury the mass had been noticed and during the year prior to admission it had grown rapidly (Fig. 15). Roentgenograms showed soft-tissue destruction about the proximal phalanx, with periosteal reaction. (Submitted by Dr. J. E. Nohlgren.)

Exploration revealed a large bony growth resembling an osteochondroma. It had not invaded the cortex and could be removed as a definite layer with a thin chisel. One year after this excision, the patient was well.

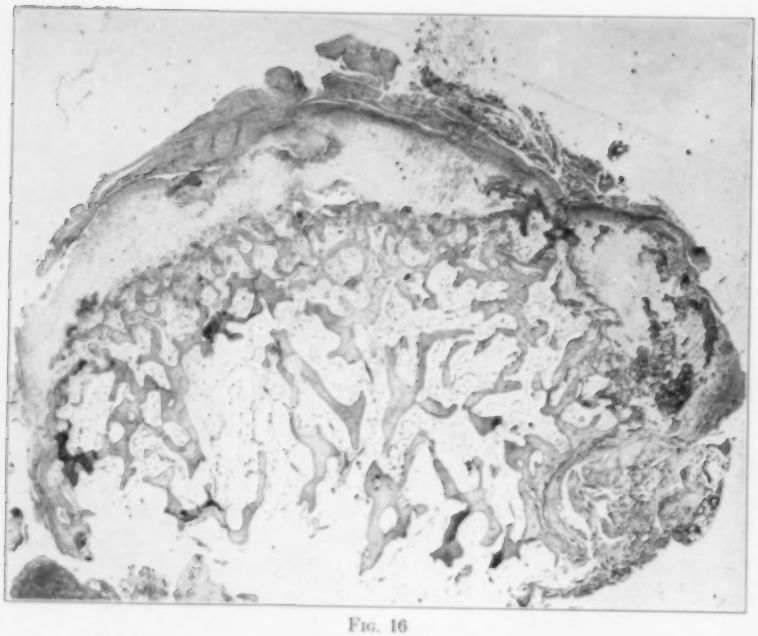

FIG. 16

Case 482. Photomicrograph (× 9.5) showing osteochondroma-like tumor with cartilaginous cap and bone pedicle. As in Case 159, endochondral ossification is taking place. One can see, however, even at this low power, areas of calcification and ossification within the cartilaginous cap, and that the distribution seems to be random. The superficial portion of the bone marrow is more fibrous than fatty.

Microscopically, this lesion showed a thick surface layer of cartilage beneath which endochondral ossification was noted. Deeper in the region, there were bone spicules with loose connective tissue and fatty tissue in the intervening spaces. Occasional bone spicules showed osteoclastic activity. Some areas in the cartilage showed definite ossification or osteoid formation. Findings atypical for osteochondroma were: the thickness of the soft tissue envelope over the cartilaginous surface and its cellularity, cartilage proliferation and dedifferentiation, and cartilage with calcification. At some distance inward, the relationship between soft-tissue elements, cartilage, and osteoid was a confused one without a regular pattern (Figs. 16 and 17).

These findings led to a diagnosis of early juxtacortical osteosarcoma, and amputation of the ray was recommended but not carried out.

CASE 611. Two months previous to examination this nine-year-old girl noticed a swelling in the nail bed of the right great toe. The mass was round and projected two millimeters above the level of the nail. It had ulcerated and was painful. Roentgenographic study revealed a poorly defined mass medial to the basal phalanx and relatively radiolucent (Fig. 18). At operation, the tumor showed a line of cleavage with a pedicle extending to the bone (Fig. 19). (Submitted by Dr. Charles P. Larson.)

Microscopic section showed a mass of myxoid connective tissue at the base of the lesion above the cortial-bone fragments (Fig. 20). The cells were moderately pleomorphic and somewhat hyperchromatic. They showed condensation in some areas to form hyaline cartilage, and in two of these areas the cartilage showed endochondral sequences. The superficial capsule was thick and exhibited chondroid and osteoid metaplasia (Fig. 21).

Although the pathologist recognized that the lesion was malignant he made a diagnosis of chondromyxoma on the basis of the fact that cartilage tumors in this location are usually clinically benign. However, at the Bone Tumor Registry, a diagnosis was made of early juxtacortical osteosarcoma. If this is the proper diagnosis, it illustrates the reason why this entity roentgenographically may appear to be not connected with the bone in which it originates. In a very

FIG. 17

Case 482. Photomicrograph (× 120) showing detail of Fig. 16. Note again the cartilage, most clearly seen at the base, undergoing the same process of dedifferentiation through fibrocartilage to fibrous connective tissue. Note also calcification of cartilage and beginning ossification—again without the orderly picture characteristic of osteochondroma. Note also vascularity of the cap.

FIG. 18

Case 611. The calcifying tumor on the medial side of the distal phalanx of the great toe is faintly seen in this roentgenogram. There is a radiolucent zone between the calcific mass and the phalanx proper.

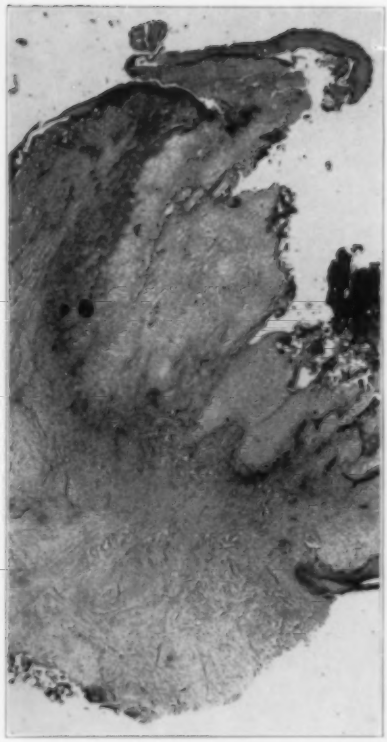

FIG. 19

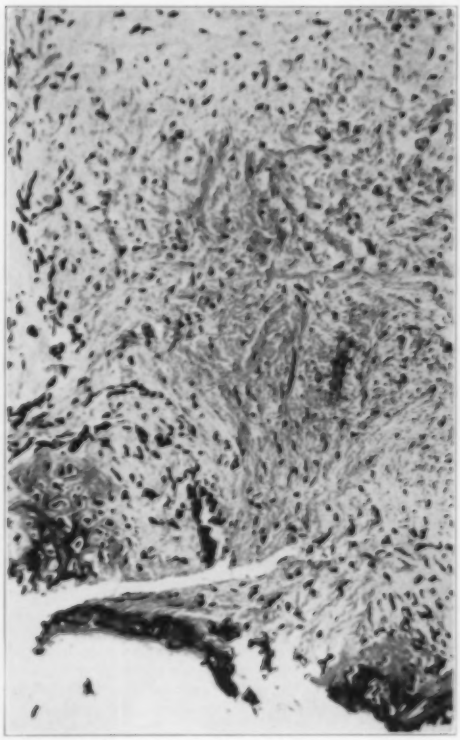

FIG. 20

Fig. 19: Case 611. Photomicrograph (× 12) showing tumor with superficial infection and ulceration. Epidermis can be seen on either side of the ulcerated area. The lighter staining area is composed of hyaline cartilage and the darker border of this area is a zone of endochondral ossification. The greater part of the tumor, its pedicle, is made up of loose fibrous connective tissue, and at its base are tiny, deeply staining bits of bone avulsed from the cortex of the phalanx.

Fig. 20: Case 611. Detail in photomicrograph (× 120) of base of tumor showing bits of cortical bone of phalanx. Above it is fibrous connective tissue. This is not highly cellular, but there is a certain amount of pleomorphism.

early lesion such as this, despite the endochondral ossification taking place beneath the cap, both the marked cellularity of the base of the lesion and of the capsule and the cellular pleomorphism and hyperchromatism negate the diagnosis of either common osteochondroma or chondromyxoma. Indeed, to my knowledge, small superficial cartilaginous tumors of bone do not usually assume a myxomatous appearance in any part, as endosteal lesions frequently do.

In their original paper on this entity, Geschickter and Copeland called attention to a characteristic and constant finding—the roentgenographic presentation of a tumor separated in some plane from the parent bone. In their published series, however, they illustrated only one case with this characteristic. The case just described is an additional example.

CASE 623. H. T., a woman, thirty-four years old, was seen with a firm mass of six months' duration on the palmar aspect of the middle phalanx of the little finger. Roentgenograms showed a mushroom-shaped radiopaque nodule, sharply demarcated (Fig. 22). A diagnosis of exostosis was made and excision was done. The specimen was pear-shaped and bony, measuring one centimeter in length and up to eight by seven millimeters in its other diameters. The stalk was four millimeters in diameter. The bone was soft, yellow, and cancellous and at the large end there was a cartilage cap two to three millimeters thick. (Submitted by Dr. Warren C. Hunter.)

Microscopic examination showed the cap to consist of hyaline cartilage which was

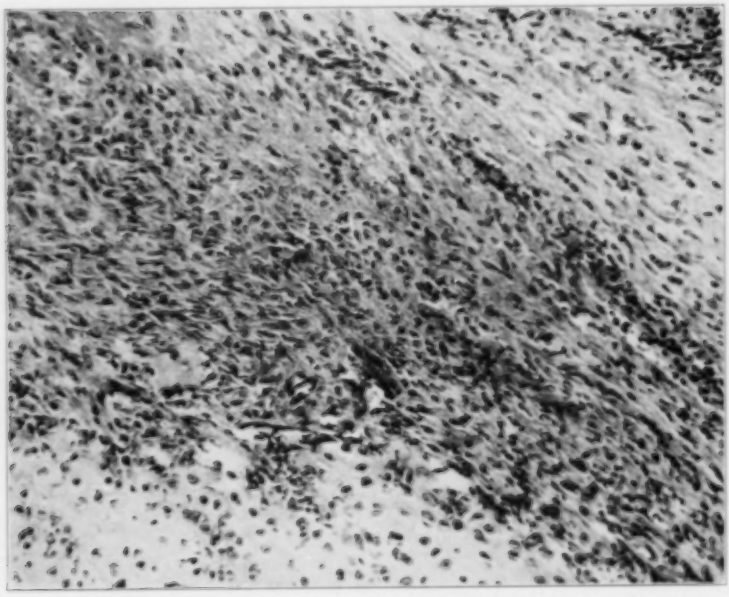

FIG. 21

Case 611. Photomicrograph (× 120) showing detail of upper portion of tumor. The superficial surface of the cartilage gives way by continuous gradation (albeit in a narrower zone than the earlier cases) to fibrous connective tissue and osteoid. A simple enchondroma does not contain such a large number of spindle cells overlying the hyaline cartilage, nor is there any osteoid to be found in that location.

FIG. 22

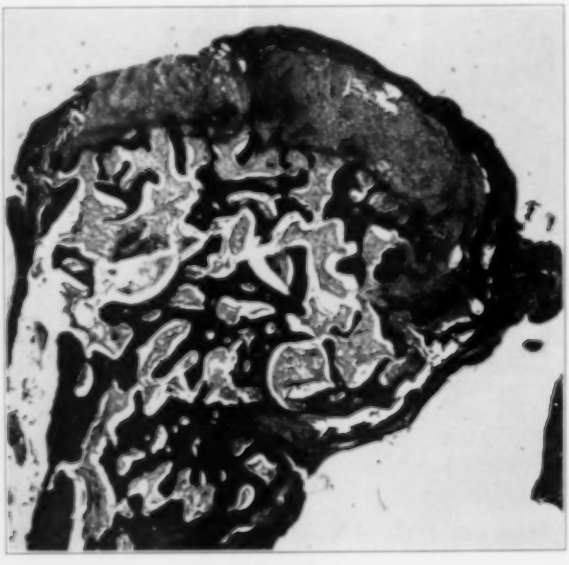

FIG. 23

Fig. 22: Case 623. Roentgenogram showing osteochondroma-like tumor of phalanx.

Fig. 23: Case 623. Photomicrograph (× 13) of resected tumor. On casual inspection, it displays the architecture of an osteochondroma—the bone pedicle, the cartilaginous cap, and between, the zone of endochondral ossification. Careful inspection, however, even at this power, reveals that the cartilaginous cap is by no means uniform in its architecture, and that the bone marrow is decidedly fibrous rather than fatty.

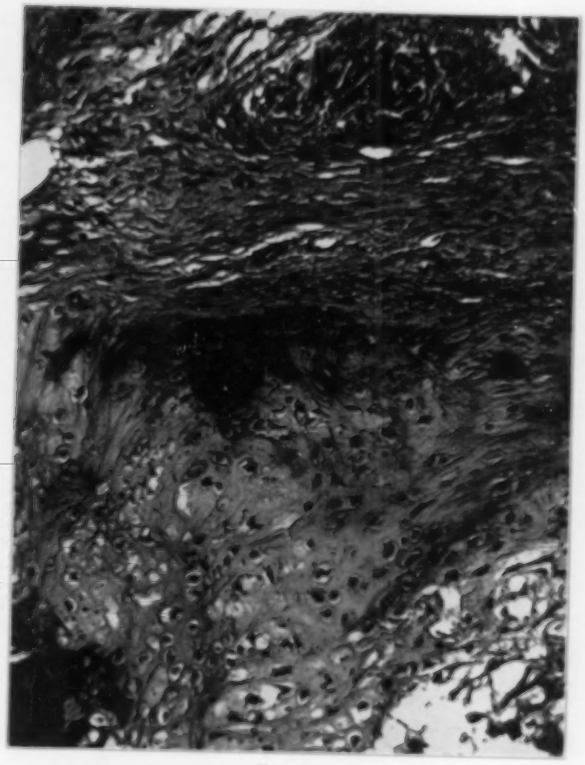

FIG. 24

Case 623. Photomicrograph (× 120) showing detail of cap of tumor. Note the gradation from hyaline cartilage at the base of the illustration through fibrocartilage to connective tissue and osteoid (the deep staining area in the middle).

hypercellular and endochondral ossification sequences were seen at its base. On its surface, there were several breaks in the perichondrium where the cartilage cells were definitely more spindle-shaped and more numerous than elsewhere. Areas of osteoid were found within the cap. A considerable number of cartilage cells had large clumped nuclei. Bone marrow was fibrous and often cellular, although the cells were isomorphic and normochromic (Figs. 23 and 24).

The original diagnosis was osteochondroma with chondrosarcomatous change, but at the Bone Tumor Registry a diagnosis of early juxtacortical osteosarcoma was made.

CASE 520. H. L., a woman, twenty years old, was seen with a swelling of five months' duration at the base of her neck (Fig. 25). The swelling was painful, had grown rapidly, and had caused local tenderness and numbness in the left arm, more pronounced in the hand and forearm. The tumor was firm, dense, tender, and firmly attached to underlying structures. Clinically the impression was that of carcinoma of the neck with infiltration of the nerve roots, or possibly malignant tumor of the vertebrae. At exploration, the lesion appeared to be osteochondroma attached to the transverse process of the fifth cervical vertebra. The lesion was removed.

There was a recurrence three years later. The tumor had grown rapidly and on palpation was hard, nodular, and apparently fixed to the cervical vertebrae. The mass measured about eight by eight centimeters, had the consistency of bone, and was not fixed to overlying structures. Roentgenograms revealed it to be about three or four times as large as it had been previously. A clinical diagnosis of chondrosarcoma was made, but the pathological diagnosis again was osteochondroma. The recurrent tumor arose from the transverse process of the fifth cervical vertebra and was removed in fragments without sacrificing any nerves. It measured about six by four centimeters and consisted of a number of cartilaginous caps surrounded and covered by membrane. It had a small base.

FIG. 25

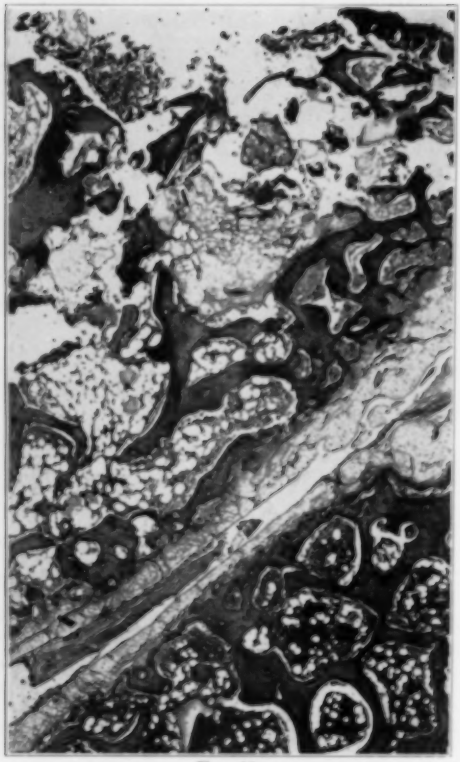

FIG. 26

Fig. 25: Case 520. Roentgenogram of osteochondroma-like lesion of transverse process of fifth cervical vertebra as it appeared before the first operation.

Fig. 26: Case 520. Photomicrograph (× 21) of section of tumor removed at first resection. Note cartilaginous cap dipping deeply, apparently along the surfaces of an interlobar fissure. Note other zones of cartilage in the interior of the bone, although it is possible that in another dimension these are connected with the surface.

Nine months after the second resection, the patient had increasing tumor growth in the neck with loss of weight and increased peripheral nerve signs, but without signs of metastasis. (Submitted by Dr. A. Peter Crane.)

Microscopic examination showed the first specimen to consist of tissue typical of osteochondroma but containing unusually deep-lying islands of cartilage (Fig. 26). The second specimen showed masses of cartilaginous tissue and bone. The cartilage was irregularly mineralized and excessively cellular, although the cells were uniform. There was no evidence of mitotic activity or of double nuclei. However, irregularly distributed areas of cartilage were present in the bone trabeculae (Fig. 27).

The more exuberant growth of cartilage, and its greater extension into the bony tissue than is usual in osteochondromata, may be emphasized as evidence for the diagnosis of juxtacortical osteosarcoma rather than osteochondroma. Additional evidence was the fibroblastic activity in the marrow, which was greater than is usual. The diagnosis was also considered justified on the basis of the findings and the recurrence of the tumor. However, it must be admitted that it would be a bold pathologist indeed who would have recommended early radical resection, were it feasible, on the basis of the histopathological study. Despite the fact that only a few stigmata of juxtacortical osteosarcoma were present in this tumor, its aggressiveness and recurrence seem to justify its inclusion under this classification.

CASE 740. D. A. E., a male, thirty-two years old, appeared with a six-week-old growth on the middle phalanx of the index finger. Roentgenographic study revealed a small exostotic lesion projecting two millimeters above the cortex. The lesion showed less density than the

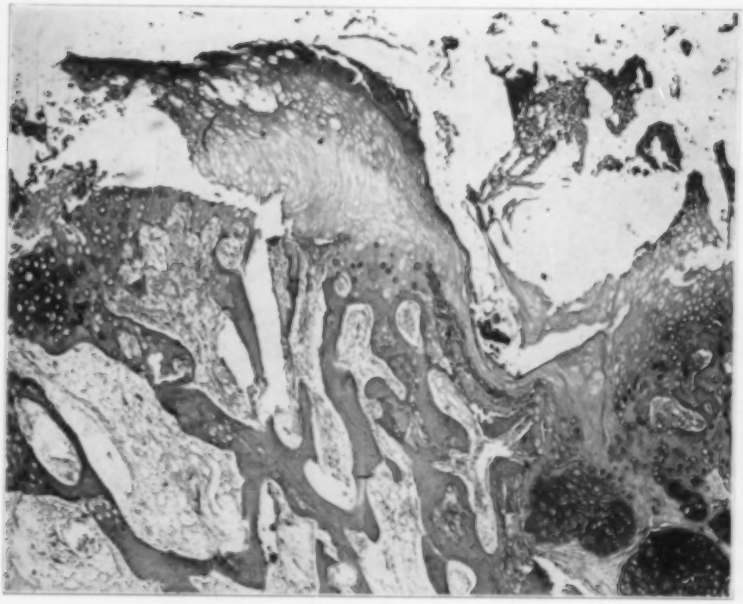

FIG. 27

Case 520. Photomicrograph (× 21) of section of tumor removed at second resection. Note the deeply placed islands of cartilage, their apparently more aggressive cellularity, and the increase in the fibrous connective-tissue marrow.

bone to which it was attached, and had finely serrated edges. Above it was a small soft-tissue swelling. The lesion was excised.

Microscopic sections showed tissue of a transitional nature between the bone and overlying neoplastic soft tissue. The tumor contained spindle-shaped connective tissue and cartilaginous cells, irregularly oriented, but not showing any atypical cellular characteristics. No mitotic figures or giant cells were seen.

DISCUSSION

The cases are summarized in Table I.

In this series amputation was performed on three patients. In two of these, osteochondroma was diagnosed or suggested early in the disease. The same was done in one of Geschickter and Copeland's cases, and in Coley's case. Dwinnell, Dahlin, and Ghormley's series of fifteen cases included six which were originally called osteochondroma, and one in which the term exostosis was used. This finding is much too frequent to be coincidental.

Dwinnell, Dahlin, and Ghormley called attention to the occurrence of cellular fibrous connective tissue within the stalk of the lesion as suggestive of a more active tumor and this series confirms it. What I consider more suggestive and which I believe to be pathognomonic is the cap in which one sees areas of unspecialized connective tissue, cartilage, and osteoid, with no recognizable polarity. In this series that finding is noted in most of the early lesions. The fibrosis and irregularity of cartilage islets may be noted particularly in Case 520, and the appropriate general appearance and contours in Case 82.

It is postulated then that we are dealing with a disease entity which initially resembles an osteochondroma in its general appearance, and probably in its pathogenesis, but is marked by three important differences:

1. Its histological variance from the simple cartilaginous exostosis;
2. Its tendency to recurrence;
3. Its occasional malignant degeneration into the entity known in the literature as parosteal osteoma or juxtacortical osteosarcoma.

TABLE I

Case	Sex	Age (*Years*)	Interval between Onset of Symptoms and First Treatment (*Months*)	Initial Diagnosis—Clinical and X-ray	Initial Pathological Diagnosis	Treatment	Outcome	Duration	Bone Region
82	F	38	Prompt	Tumor	Osteoid osteoma, probably began in an osteochondroma	Resection; 1 yr. later, x-ray; 15 mos. later, disarticulation	Died, apparently of pulmonary metastasis	4 yrs.	Femoral metaphysis
159	F	26	6	Osteochondroma, with the reservation that the suggestion of formation of spicules might indicate malignant change	Osteitis fibrosa; 1 yr. later, osteochondroma	None; 1 yr. later, excision; 14 mos. later, excision; 4 yrs. later, amputation through upper one-third of femur	Living and well 5 yrs. after amputation	9 yrs.	Femoral metaphysis
277	M	18	3	Possible osteogenic sarcoma	Myositis ossificans with disturbance in underlying bone suggesting the possibility of parosteal osteoma; 1 mo. later, second biopsy, parosteal osteoma	Amputation	Living and well 4 yrs. after amputation	4½ yrs.	Femoral metaphysis
482	M	36	24	Not stated, evidently benign	Osteochondroma	Injection into finger to dissolve the calcium; excision	Living and well 1 yr. after excision	5 yrs.	Phalanx, metaphysis
520	F	20	5	Malignant tumor	Osteochondroma; 3½ yrs. later, recurrent osteochondroma	Excision; 3½ yrs. later, excision	Recurrence	4 yrs., 7 mos.	Vertebra, transverse process
611	F	11	2	Tumor	Chondromyxoma	Excision			Phalanx, base
623	F	34	6	Exostosis	Osteochondroma with chondrosarcomatous changes	Excision			Phalanx, basal half
740	M	32	1½	Exostosis	Possible osteochondroma, enchondroma, or parosteal osteoma	Excision		3 mos.	Phalanx, metaphysis

The tumor has, apparently from its inception, a less limited growth-potential than the classic cartilaginous exostosis; quite early, therefore, its growth may proceed both away from and into the bone. Penetration of the cortex is not too difficult to understand; the cartilaginous exostosis has a central marrow cavity which is often continuous with its bone of origin.

The nidus of growing tumor cells transmits its aggressiveness to its daughter cells, both cartilaginous and stromal.

The papers of Müller and of Jacobson [4] present osteochondroma as originating in the periosteum by metaplasia and proliferation of clusters of cells in the cambium layer. As Jacobson pointed out, when cartilage and bone are growing in juxtaposition one to another they assume the architectural characteristic of an epiphyseal growth plate. This contributes to the characteristic structure of osteochondroma, and, it is suggested, to the early tumor discussed here.

In 1940 Jacobson [5] published a classification of bone tumors in which osteochondroma (and ivory exostosis) and periosteal osteogenic sarcoma were presented as the benign and malignant forms, respectively, of a tumor of the periosteum. The entity discussed in this article offers a lesion of an intermediate grade of aggressiveness which partakes of the characteristics of each in the different stages in its development. In 1953, Jacobson in an exhibit at the annual meeting of the American Society of Clinical Pathologists presented some published and some new cases of parosteal osteoma and developed the thesis that it arises in the same fashion as osteochondroma, but has from the beginning greater growth potentialities. In order to make a critical survey of cases of secondary malignant degeneration of osteochondromata a search was made of the literature. Unfortunately, in most of the reports the paucity of both illustrations and descriptions made it impossible to establish definitely the character either of the original lesion or of its malignant degeneration. Both diagnoses had to be accepted on faith, if at all.

In Geschickter and Copeland's original papers, stress is laid upon the apparent separation, as seen in roentgenograms, between tumor and bone in some plane, although it is seen in only one of their illustrations. This hiatus is illustrated and may be explained by Case 611 of this study. As stated before, the early exostotic lesions generally bear cartilaginous caps. However, in one case (seen through the courtesy of the Armed Forces Institute of Pathology), this is lacking. Whether or not cartilage casts a shadow on the roentgenographic plate depends primarily on its calcium content. Characteristically, the cartilaginous cap of an osteochondroma is not visible, nor is its connective-tissue content. If, therefore, proliferation causes the cartilaginous cap of a tumor to become thick and perhaps continuous (as shown in some of the cases reported) with superficial neoplastic osseous, or deeper neoplastic connective tissue, there might well be no calcific matter in it to cast a shadow on the roentgenogram; apparent discontinuity of the superficial ossifying part of the tumor and the deeper bone will result.

As suggested above, it is not as yet by any means certain that in all cases simple resection of the early tumor is followed by its more malignant recurrence. It could be, in essence, a premalignant disease, analogous to certain dermatoses, whose further progression is not inevitable. Judgment must be withheld, on the ground of both the relatively recent appearance of the disease in some of these cases, and of the small total number submitted. It is probable that these tumors are considerably less common than the banal osteochondroma; there is a tendency on the part of contributing pathologists not to send the perfectly obvious, simple, benign pathological entities to the Bone Tumor Registry. They are much more likely to communicate with the Registry when something unusual about the microscopic picture might suggest difficulty in diagnosis. Then too, within the past year or so, several pathologists in this area have been asked to be on the alert for and to identify such lesions as have been described.

Four of the present series of eight cases were phalangeal tumors, three were femoral, and one was vertebral. The last four cases entailed, at present writing, serious consequences. The saving grace in digital growths, such as seen in the first four cases, may well be the fact they are observed and removed in an early stage.

It should be remarked that there is no inherent reason why the neoplastic periosteal activity must include a cartilaginous phase. By courtesy of the Armed Forces Institute of Pathology, the writer has seen what was called a parosteal osteoma in which no cartilage cells were to be found, nor did they appear in Case 82 of this report. It may furthermore be anticipated that such a tumor, arising upon that part of the skeleton which ossifies in membrane would regularly, like an ivory exostosis, be cartilage-free.

It is further to be borne in mind that there is no reason why the endosteum should not also be capable of neoplastic activity of an intermediate degree of malignancy between the activity of medullary osteosarcoma and that of osteoid osteoma, which Jacobson, in the classification previously referred to, considered its benign counterpart. The writer is informed that at least one such tumor has been seen at the Armed Forces Institute of Pathology, and the same diagnosis has been made at this Registry. Such cases, however, fall outside the scope of this report.

The corollary conclusion is that all exostoses should be submitted to microscopic examination.

It is impossible as yet to give definite advice as to treatment. For the time being, the writer is inclined to be content with wide excision of the original lesion, but upon recurrence he would recommend a more aggressive attack, if such be surgically feasible. If confirmatory evidence of the relationship between these tumors and fully developed sarcoma should appear, then recurrence of the lesion should be an indication for amputation.

There has been little experience with radiation therapy in this disease. At first thought, one would not expect it to be effective; nevertheless, when the lesion is surgically inaccessible, and has already shown ominous tendencies (Case 520), irradiation may be attempted.

SUMMARY

An osteochondroma-like lesion represents the beginning of juxtacortical osteosarcoma. This may be differentiated from simple osteochondroma by the irregular development of masses of connective tissue, fibrocartilage, and osteoid, in and on the cartilaginous cap of the lesion, and also by the appearance of more than a minimal amount of connective-tissue stroma in the marrow cavity of the bony stalk.

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Treatment by Bone-Grafting of Aseptic Necrosis of the Femoral Head and Non-Union of the Femoral Neck (Phemister Technique)*

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Aseptic necrosis of the femoral head secondary to intracapsular fractures and traumatic dislocation of the hip leads to serious hip disability if untreated. The pathology of aseptic necrosis has been reported by many authors but this knowledge has not been utilized adequately in diagnosis and therapy because no effective treatment has been reported in a large enough series of patients for adequate evaluation of the results. Bone transplants have been used effectively in the treatment of recent and ununited fractures of the femoral neck. However, bone transplants have not often been used to hasten restitution and avoid collapse of the head of the femur while it undergoes replacement.

The observations by Phemister [4,5] and Compere and Lee of good function in a few patients with aseptic necrosis of the femoral head and ununited fractures of the femoral neck treated by the insertion of two tibial-bone grafts into the superior and anterior segment led to an experimental study in dogs by one of us [2]. The results indicated that revascularization of the necrotic femoral head in dogs could be aided by drilling, and collapse of the head could be prevented by inserting a supportive bone graft. In addition, ossification along the bone graft aided union between the head and neck.

During the past seven years, fifty-three patients with varying amounts of aseptic necrosis of the femoral head and with or without non-union of fractures of the femoral neck have been treated by the insertion of two autogenous cortical-bone grafts. By means of a two plane roentgenographic control, grafts are placed in the superior anterior quadrant of the femoral head in order to support the area most vulnerable to collapse. Grafts alone were used in those patients with union of the fracture and aseptic necrosis, or necrosis alone from other causes.

Two one-centimeter plugs of cancellous bone with the overlying articular cortex and cartilage are removed from the femoral head to obtain a biopsy specimen and to allow the insertion of the cortical-bone grafts up to the articular cortex in order to achieve maximum support in the weight-bearing area which has a tendency to collapse and to initiate osteogenesis by new vascular connective tissue which grows along the grafts to the subchondral region. In most of the patients tibial transplants from the same extremity were used and in a few others, split fibular grafts. Three five-thirty-seconds of an inch threaded Steinmann pins are inserted below the grafts as additional fixation when non-union is present.

Fixation of the head and neck is performed *in situ* when the ununited fracture is in a reasonably satisfactory position. Open reduction is rarely necessary since *in situ* fixation or closed reduction usually gives a satisfactory position and precludes further loss of blood supply by disturbing the intermediary callus and visceral capsule. In a few instances, the operation was performed in order to

*Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, New York, N. Y., February 3, 1958.

restore blood supply to necrotic bone of the femoral head preliminary to and in preparation for cup arthroplasty.

The average hospital stay is ten to fourteen days. During the period from April 1950 to October 1955, sixty-one patients were operated on at the State University of Iowa Hospitals. Eight of these patients are not included in the analysis of results because of death or incomplete follow-up. An evaluation of fifty-three patients (fifty-five operations) followed for two years or longer forms the basis of this report. Table I shows the analysis of the patients studied according to the

TABLE I

ANALYSIS OF PATIENTS EVALUATED

Clinical and Pathological Diagnosis	No. of Patients	Time to Crutch-Walking (*Months*)	Average Length of Follow-up
Minimal to moderate aseptic necrosis of femoral head with non-union of fractured neck	13	10	3 yrs., 10 mos.
Aseptic necrosis of femoral head with non-union of fractured neck	22	12	3 yrs., 11 mos.
Aseptic necrosis of femoral head	18	12	4 yrs.
a. with united fracture of femoral neck	8		
b. after dislocation	3		
c. idiopathic—trauma or vascular occlusion, 2 patients bilateral	7		
Total number of patients	53		3 yrs., 11 mos.
Total number of hip operations	55		(span, 2 yrs. to 6½ yrs.)

TABLE II

ANALYSIS OF CLINICAL RESULTS
(55 operations, 53 patients)

Minimal aseptic necrosis of the femoral head with non-union of the neck					
Good,	4	Excellent,	7		11 (85%)
Poor,	2				2 (15%)
				Total	13
Aseptic necrosis of the femoral head with non-union of the neck					
Good,	10	Excellent,	6		16 (73%)
Fair,	3	Poor,	3		6 (27%)
				Total	22
Aseptic necrosis of the femoral head					
Good,	11	Excellent,	3		14 (70%)
Fair,	5	Poor,	1		6 (30%)
				Total	20

clinical and pathological diagnosis and includes the average time of follow-up in each category and the average length of time of protected weight-bearing. The period of protected weight-bearing was determined by roentgenographic evidence of bone union at the fracture site and the conversion of the necrotic fragment to living bone. This repair of dead bone was frequently difficult to assess by roentgenographic means, but in general, one most frequently noted an increase in density as new bone was deposited on the necrotic bone during the process of creeping substitution. At times, a decrease in bone density preceded the deposition of new bone. As a rule, the patient was advised to test the hip by a program of gradually in-

creasing weight-bearing over a period of two to three months. A roentgenographic check was made at the end of this period. If no further collapse had occurred and the patient had no pain from gradually increasing weight-bearing, the patient would then be allowed to bear weight without crutches.

RESULTS

In the evaluation of each patient the following factors have been considered both preoperatively and postoperatively: functional ability, pain, deformity, gait, and range of motion. A numerical rating system utilizing these factors in the evaluation of hip operations is being tested in the Orthopaedic Department at the State University of Iowa Hospitals. This was checked against the authors clinical rating of *excellent*, *good*, *fair*, and *poor*. As a further check we used the Stinchfield modification of the Judet rating system. In general, our system of grading rated the end result the same or lower than the Judet ratings; in each instance the most

TABLE III

ANALYSIS OF THE ROENTGENOGRAPHIC RESULTS

	Restoration of Bone Union, Femoral Neck and Head		Graft Fracture	Further Collapse, Necrotic Femoral Head				Degenerative Joint Change			
	Union	Failed		None	Minimal	Moderate	Severe	None	Minimal	Moderate	Severe
Non-union of the femoral-neck fracture with minimal aseptic necrosis	11	2	2					8 (2 preoperative)	4	1	
Non-union of the femoral-neck with aseptic necrosis of the femoral head	20	2	2	14	5	2	1	7 (3 preoperative)	9	3	3
Aseptic necrosis of the femoral head				17	2		1		2 (18 preoperative)	15	3
Sub-totals				31	7	2	2	15	15	19	6
Totals	31 (89%)	4 (11%)	4	31 (74%)		11 (26%)		15 (27%)		40 (73%)	

critical rating was used to express the result (Table II). Additional factors considered were roentgenographic evidence of bone union, arrest of further collapse of necrotic bone, and secondary degenerative arthritis (Table III).

Minimal to Moderate Aseptic Necrosis of the Femoral Head with Non-union of the Fractured Femoral Neck

Eleven of the thirteen patients in this group had a satisfactory end result. It is interesting to report that although an ununited fractured femoral neck was the primary problem in these patients, a study of the biopsy material showed minimal to moderate necrosis of the femoral head in most instances. These cases are cited here to emphasize the value of bone-grafting, rather than prosthesis, in the treatment of an ununited fractured femoral neck when necrosis of the head was not a major problem. However, it is important to note that the degree of femoral-head necrosis could not be determined without microscopic study of the core biopsy. Furthermore, the pathological findings could only reflect on the status of the femoral head area at the time of biopsy. The residual areas of necrosis varied according to degree of vascular interruption at the time of injury, the interval after injury, and the rate of replacement of dead bone. The patients' ages ranged from

FIG. 1-A

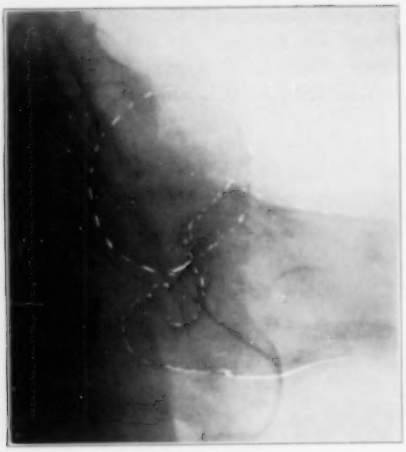

FIG. 1-B

Figs. 1-A through 1-G: Case 1. M. T., a woman, sixty-two years old, had had an ununited fracture of the left femoral neck for fifteen months.

Figs. 1-A and 1-B: Preoperative roentgenograms of the left hip show displacement of the fragments.

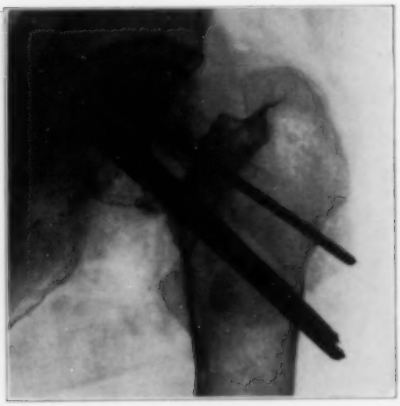

FIG. 1-C

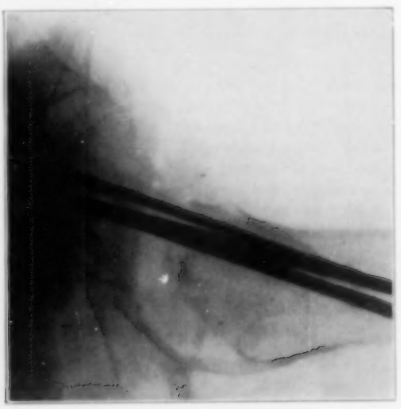

FIG. 1-D

Roentgenograms showing the postoperative position of the grafts and pins.

thirty-five to eighty-one years. Four patients were under sixty years of age and four were over seventy. The interval of non-union or displacement of the fractured femoral neck ranged from two months to two and one-half years. The average time of protected weight-bearing on the involved extremity was ten months. Gradual increase in weight-bearing was started two to three months sooner.

Case 1, a patient operated on four and one-half years ago, illustrates reconstitution of the femoral neck about the transplants:

CASE 1. M. T., a woman, sixty-two years old, had had an ununited fracture of the left femoral neck for fifteen months. Displacement of the fragments was apparent in the roentgenograms of the left hip (Figs. 1-A and 1-B). The head appeared to be viable. Closed reduction was obtained by traction, abduction, and internal rotation on the fracture table. Through a lateral approach to the greater trochanteric area of the femur, two guide pins were inserted into the superior half of the head and neck and two threaded Steinmann pins into the inferior half. Following removal of the guide pins, biopsy specimens were taken and two cortical tibial grafts inserted into the channels. An additional threaded pin was inserted for further stability. Figures 1-C and 1-D show the postoperative position of the grafts and pins. The patient was allowed on crutches bearing no weight on the left, and discharged from the hospital thirteen days after operation. At four months bone union of the femoral-neck fracture

was apparent but full weight-bearing was not allowed until eight months after surgery. Reconstitution of the femoral neck is best shown at fourteen months in a lateral roentgenogram of the hip (Fig. 1-E). Four and one-half years after internal fixation and bone-grafting the patient had an excellent clinical result (Figs. 1-F and 1-G).

The report of the following case in which failure of the procedure occurred illustrates the importance of proper placement of the bone transplants and threaded pins:

CASE 2. J. C., a man, sixty-three years old, had had an ununited fracture of the right femoral neck for one year. Roentgenograms of the right hip showed a viable femoral head with displacement and moderate absorption of the neck. Drilling and insertion of two tibial grafts and three threaded pins, after closed reduction by traction and internal rotation and abduction, was performed. The core biopsy revealed a pseudarthrosis of the neck with viable bone. Poor placement of grafts and pins in the posterior superior quadrant of the head and neck was apparent in the postoperative roentgenograms. Within nine months, downward displacement of the head and loosening of the pins had occurred. The grafts remained intact. The patient had a Thompson prosthesis inserted at twenty-one months.

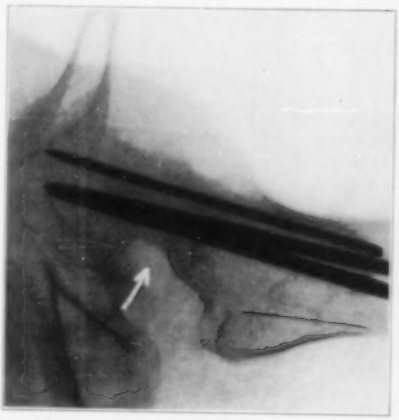

FIG. 1-E

Lateral roentgenogram of the hip made fourteen months postoperatively shows reconstitution of the femoral neck.

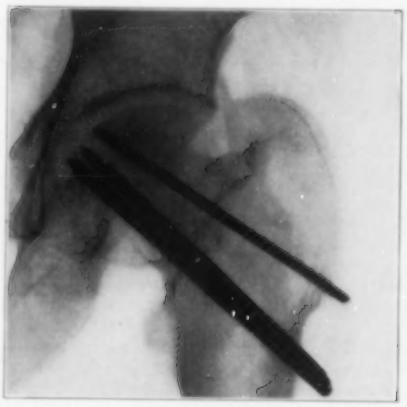

FIG. 1-F

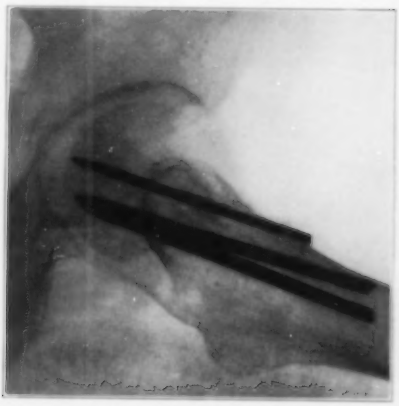

FIG. 1-G

Four and one-half years after surgery.

Failure of the procedure probably could have been avoided by accurate placement of grafts and pins to insure a better hold on the femoral-head fragment in an unstable ununited fracture.

Aseptic Necrosis with Non-Union

Sixteen of the twenty-two patients in this group had a satisfactory result. All of the patients had had ununited femoral-neck fracture with incomplete replacement of the dead bone of the femoral head as verified by core biopsy. The age of these patients ranged from thirty-eight to seventy-five years. The time interval between operative procedure and fracture of the femoral neck varied from three

months to four years with an average of fourteen months. The average time to full weight-bearing after bone-grafting and internal fixation was twelve months with a span of six to eighteen months. The average follow-up was three years and ten months. The following cases show the clinical and pathological features of this group:

Case 3. M. F., a sixty-three-year-old woman, had had a fractured femoral neck treated with a Smith-Petersen nail six months earlier. Roentgenograms of the right hip showed extrusion of the nail, loss of position of the fracture, and persistent necrotic bone in the upper half of the femoral head (Figs. 2-A and 2-B). Subsequent roentgenograms showed that union of the fracture was present six months after insertion of threaded pins and two tibial grafts which extended to the articular cortex of the anterior half of the head. Photomicrographs made from the biopsy material showed necrotic subchondral cortex (Fig. 2-C) and fibrosis of the marrow in a zone of living and dead bone near the subchondral cortex (Fig. 2-D). At five years after surgery the patient had an excellent functional result although the roentgenograms of the hip showed small marginal osteophytes on the head due to mild arthritis which is superimposed on the process of aseptic necrosis in many cases (Figs. 2-E and 2-F). The degree of arthritis is related to the change in shape of the femoral head.

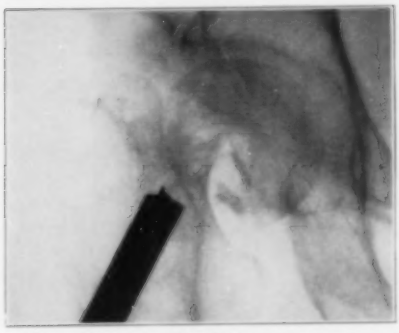

Fig. 2-A

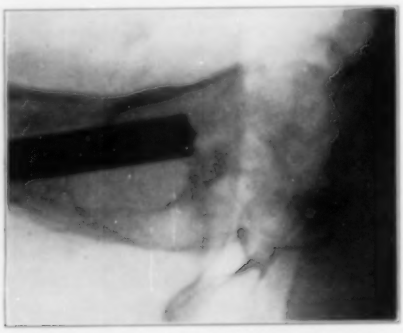

Fig. 2-B

Figs. 2-A through 2-F: Case 3. M. F., a woman, sixty-three years old, had had a fractured femoral neck treated with a Smith-Petersen nail six months earlier.
Figs. 2-A and 2-B: Preoperative roentgenograms of the right hip show extrusion of the nail, loss of position of the fracture, and partial aseptic necrosis of the head.

Case 4. D. N., a sixty-two-year-old male, had non-union of a fractured left femoral neck treated sixteen months earlier with a lag screw. In addition to the non-union, the roentgenogram of the hip revealed a moderate degree of residual necrosis of the femoral head (Fig. 3-A). Through a lateral incision, threaded pins were inserted inferiorly prior to removal of the lag screw. Graft channels were made in the old screw site and anteriorly and superiorly to it. Biopsy specimens were removed at the same time; histological examination of the superior area specimen showed a zone of necrotic bone near the articular cortex invaded by fibrous tissue in which new bone had formed (Fig. 3-C). At the time of last examination, four years and five months after operation, the roentgenogram showed no breakdown of the femoral head (Fig. 3-B). The patient had an excellent result.

Case 5. C. O., a fifty-one-year-old woman, had non-union with displacement of a fractured left femoral neck sixteen months after internal fixation with a Lorenz lag screw. A roentgenogram showed increased density of the femoral head (Fig. 4-A). Through a combined anterolateral approach an open reduction of the ununited fracture was performed after removal of the lag screw. Two tibial transplants were placed in the superior half of the femoral head through the neck and trochanter and three threaded pins were used for fixation (Fig. 4-B). Roentgenograms made four years after operation showed union of the fracture and replacement of the upper weight-bearing half of the femoral head (Fig. 4-C). The patient has walked unsupported and without pain since eighteen months after surgery; the functional result was excellent.

In Case 5, it should be noted that the medial non-weight-bearing portion of the femoral head still shows the uniform preoperative density which represents persistence of necrotic bones, while the weight-bearing area of the head in which the graft was inserted has been revascularized.

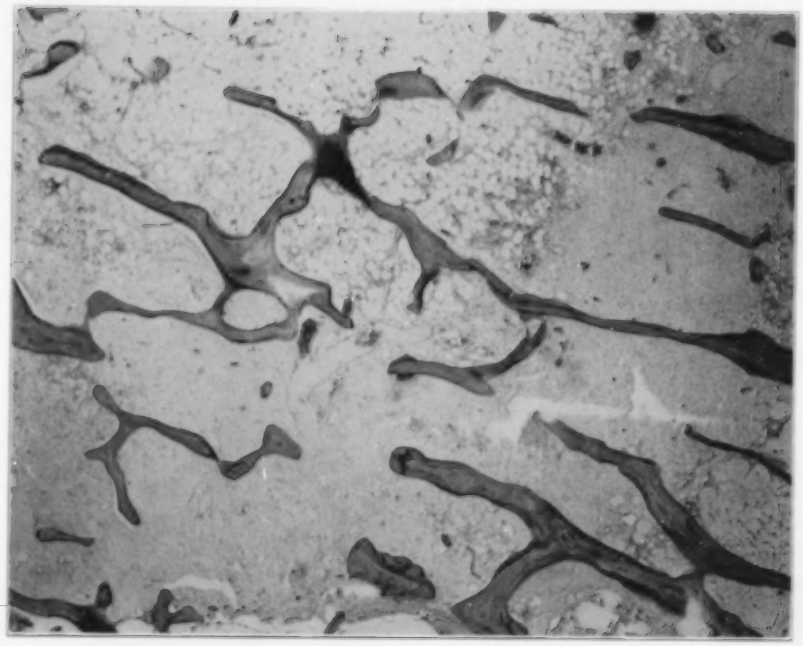

FIG. 2-D

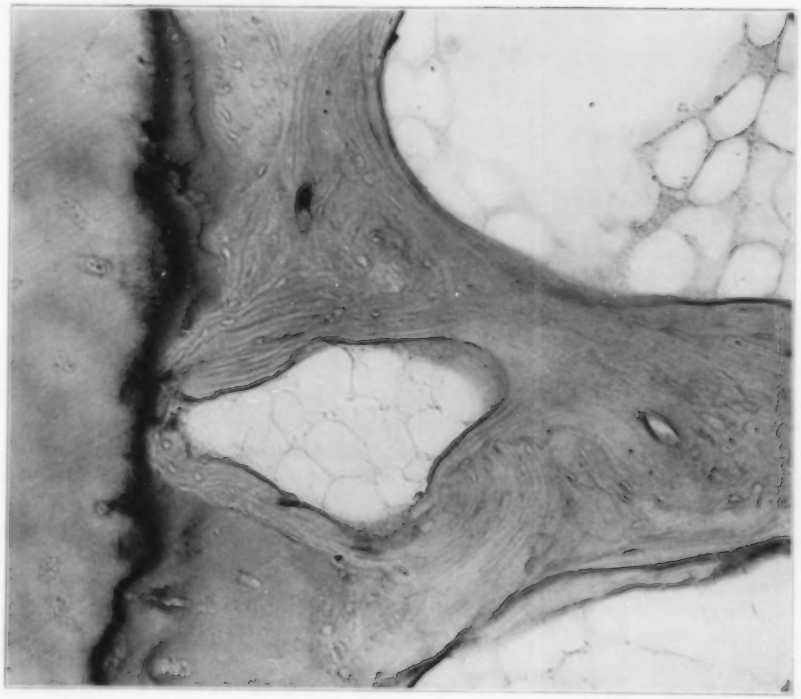

FIG. 2-C

Fig. 2-C: Photomicrograph (× 100) made from the biopsy specimen of the femoral head shows necrotic subchondral cortex.
Fig. 2-D: Photomicrograph (× 20) indicates that fibrosis of the marrow in a zone of living and dead bone is present.

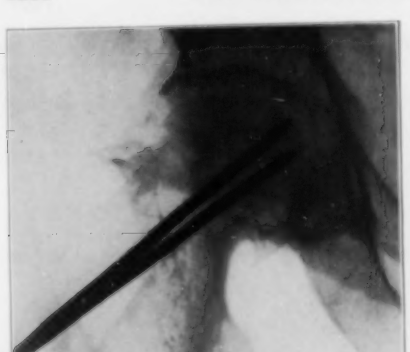

FIG. 2-E

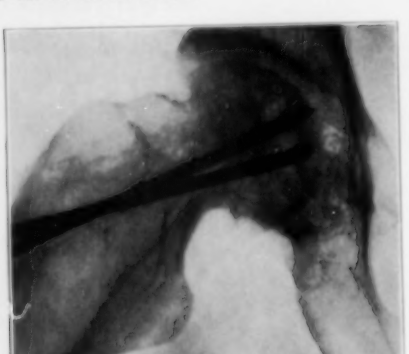

FIG. 2-F

Roentgenograms of the hip made five years postoperatively.

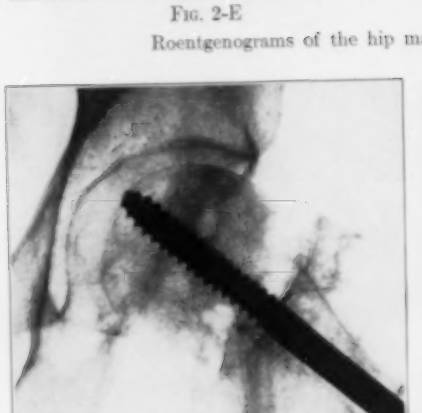

FIG. 3-A

FIG. 3-B

Figs. 3-A through 3-C: Case 4. D. N., a man, sixty-two years old, had non-union of a fractured left femoral neck treated sixteen months earlier with a lag screw.

Fig. 3-A: A roentgenogram of the hip made at admission revealed a moderate degree of necrosis of the femoral head in addition to non-union of the hip.

Fig. 3-B: Roentgenogram made four years and five months after operation shows union of the femoral neck and no breakdown of the head.

The next case emphasizes the principle expressed by Banks and Sherman and Phemister, that unprotected or too early weight-bearing on a dead femoral head leads to collapse and breakdown of the necrotic bone. It also stresses the importance of accurate placement of the bone grafts into the weight-bearing area.

CASE 6. K. L., a seventy-four-year-old woman with ununited fractured femoral neck of four months duration, was treated by *in situ* bone-grafting and insertion of two threaded pins. The relative increased density of the femoral head as compared to the intertrochanteric region is shown in the preoperative roentgenograms (Figs. 5-A and 5-B). Examination of a biopsy specimen revealed necrosis of bone in the femoral-head fragment. Three and one-half months after surgery the fracture appeared to be united and the patient was allowed to begin gradual weight-bearing. Lateral-view roentgenograms made at the time showed the bone grafts to be centrally placed in the head (Fig. 5-C). Collapse secondary to refracture of the necrotic weight-bearing area of the femoral head anterior to the grafts is obvious in the roentgenograms made eight months after the operation (Fig. 5-D). The medial portion of the head and neck remained united. During a six-year period of observation the patient has had few complaints in spite of progressive restriction of motion and further collapse of the femoral head and degenerative changes (Figs. 5-E and 5-F). The result was rated *fair*, thus classed as unsatisfactory.

FIG. 3-C

A photomicrograph (× 20) made from the biopsy specimen shows a zone of necrotic bone invaded by fibrous tissue in which new bone has formed.

Aseptic Necrosis of the Femoral Head

Fourteen of twenty operations performed upon eighteen patients restored the hip to a satisfactory status. Seventeen of the hips operated on had two tibial grafts inserted and three had only one graft. As listed in Table I, these patients had aseptic necrosis of the femoral head with minimal, moderate, or severe collapse of the necrotic area at the junction of living and dead bone. In most instances the necrosis went undetected until pain heralded the onset of collapse of a necrotic area. In fact, considerable additional delay in treatment usually took place after the onset of pain and collapse. The average time of follow-up after bone-grafting was four years. The period of protected weight-bearing ranged from seven months to two years with an average time of twelve months. The shortest period was in patients with segmental areas of necrosis of the femoral head.

In the patients with aseptic necrosis of the femoral head accompanied by united femoral-neck fracture, the ages ranged from thirteen to seventy-five years. They were first seen as late as four years after injury. These patients had a pain-free interval followed by a return of symptoms. Revascularization of a necrotic segment of femoral head without further collapse is shown in the next two cases:

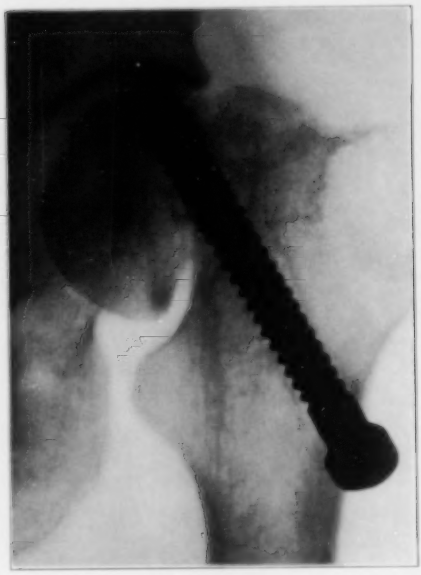

FIG. 4-A

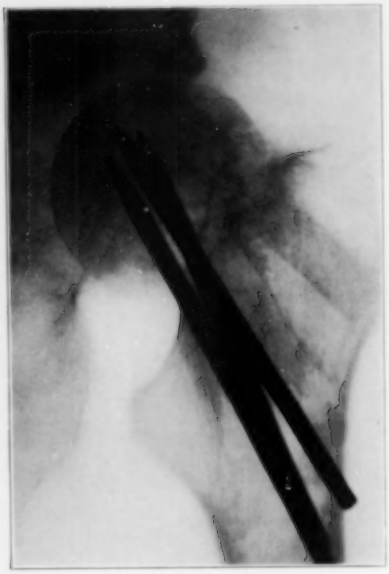

FIG. 4-B

Figs. 4-A through 4-C: Case 5. C. O., a woman, fifty-one years old, had non-union with displacement of a fractured left femoral neck sixteen months after internal fixation with a Lorenz lag screw.

Fig. 4-A: Preoperative roentgenogram of the hip shows increased density of the femoral head.

Fig. 4-B: Roentgenogram made after open reduction shows grafts in the superior half of head.

Fig. 4-C: Roentgenogram four years after operation shows union of the fracture and replacement of the upper weight-bearing half of the head, whereas the medial half shows persistence of original density.

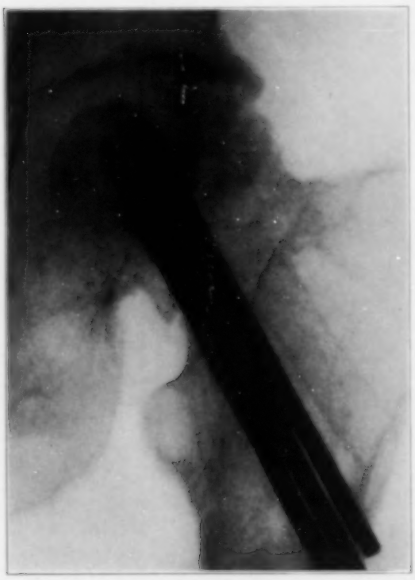

FIG. 4-C

Figs. 5-A through 5-F: Case 6. K. L., a woman, seventy-four years old, with an ununited fractured right femoral neck of four months duration, was treated by *in situ* drilling, bone grafting, and insertion of two threaded pins.

Figs. 5-A and 5-B: The relative increased density of the femoral head as compared to the intertrochanteric region is demonstrated in the preoperative roentgenograms.

Fig. 5-C: Roentgenograms made three and a half months after surgery show union of the fracture. Note that the bone grafts are centrally placed in the head in the lateral-view roentgenogram.

Fig. 5-D: Collapse secondary to refracture of the necrotic weight-bearing area of the head anterior to the grafts is obvious in the roentgenograms made eight months after the operation.

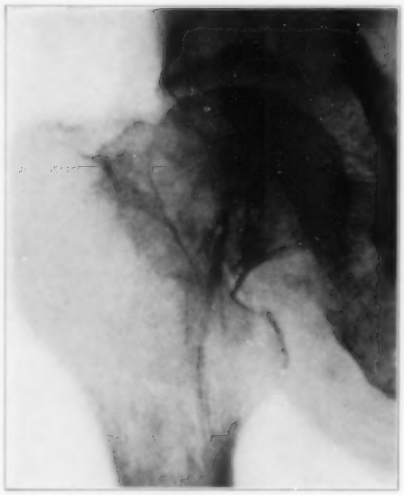

FIG. 5-A

FIG. 5-B

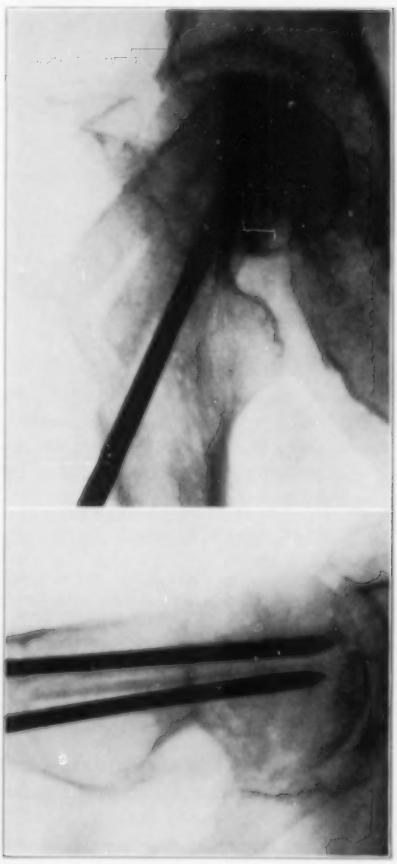

FIG. 5-C

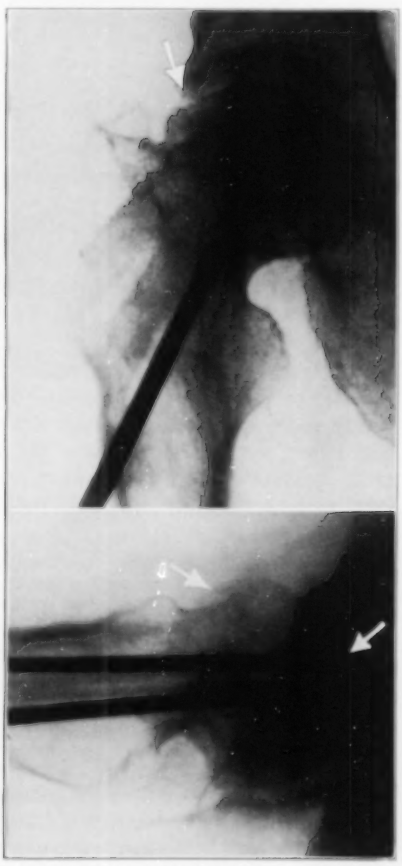

FIG. 5-D

CASE 7. C. V., a man, twenty-two years old, had had a left femoral-neck fracture treated by Smith-Petersen nailing two and one-half years earlier. The patient got along well for two years before the occurrence of pain in his left hip and knee on walking and sitting. Roentgenograms made prior to removal of the trifin nail and biopsy and bone-grafting procedures, showed slight depression of the necrotic weight-bearing area of the femoral head (Fig. 6-A). The patient walked on crutches bearing no weight for ten months and gradually returned to full weight-bearing at eighteen months. Complete revascularization without further collapse of the head was apparent in roentgenograms of the hip made two years later (Fig. 6-B). Marginal osteophytes which were present earlier increased in size, but apparently did not interfere with function.

CASE 8. E. R., a woman, sixty-two years old, was seen four years after internal fixation of a fractured right femoral neck. A collapsed segmental area of necrosis proximal and superior to the Smith-Petersen nail was evident in the roentgenogram of the hip. Roentgenograms made nineteen months and three years after operation showed repair of the necrotic fragment without additional collapse of the head. The patient's result is satisfactory.

FIG. 5-E

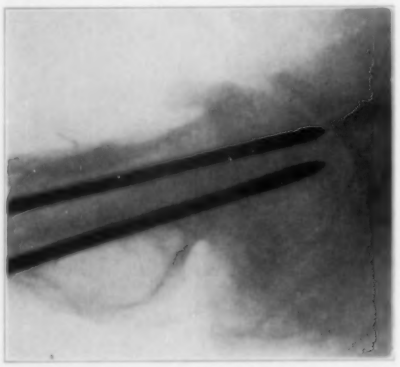

FIG. 5-F

FIGS. 5-E and 5-F: Roentgenograms made six years after operation show further collapse of the anterior superior portion of the head and degenerative changes.

The three patients with necrosis of the femoral head after dislocation of the hip were under thirty-five years of age. The intervals between examination and injury were two, five, and six years. The duration of symptoms prior to operation was eleven months, three years, and six years, respectively. Absorption of necrotic bone after drilling and bone-grafting sometimes precedes replacement by new bone as shown in this next patient:

CASE 9. W. G., a thirty-five-year-old male, had had a posterior dislocation of the hip reduced two years earlier. He was protected from weight-bearing for twelve weeks. The onset of hip pain and limp occurred for the first time thirteen months after dislocation, and recurred thereafter. Roentgenograms made two years after dislocation showed a central area of necrosis in the femoral head (Fig. 7-A). Ten and one-half months after insertion of two tibial grafts, marked reduction in density of the central area of necrotic bone was apparent in Figure 7-B which also showed the grafts projecting to the level of the subchondral cortex. At twenty-seven months a roentgenogram revealed reossification of this area, slight narrowing of the cartilage shadow, a marginal osteophyte, and increased density of the femoral head (Fig. 7-C). The patient was free from pain, walked with a slight limp, and had an excellent functional result.

The presence of increased density of the femoral head in the late stages of repair of necrotic bone does not indicate more aseptic necrosis but rather the deposition of new living bone on old necrotic or partially replaced bone.

The patients in the idiopathic group ranged in age from thirty-five to sixty-one years. Symptoms were present from nine months to seven years prior to treatment.

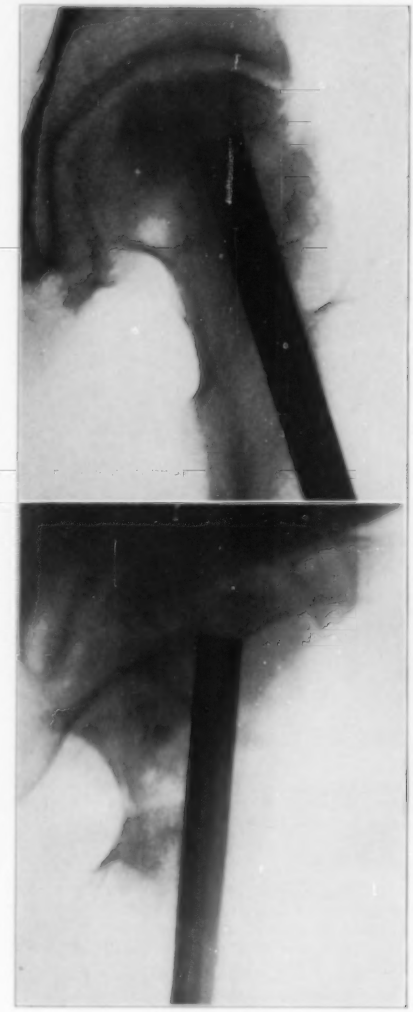

FIG. 6-A

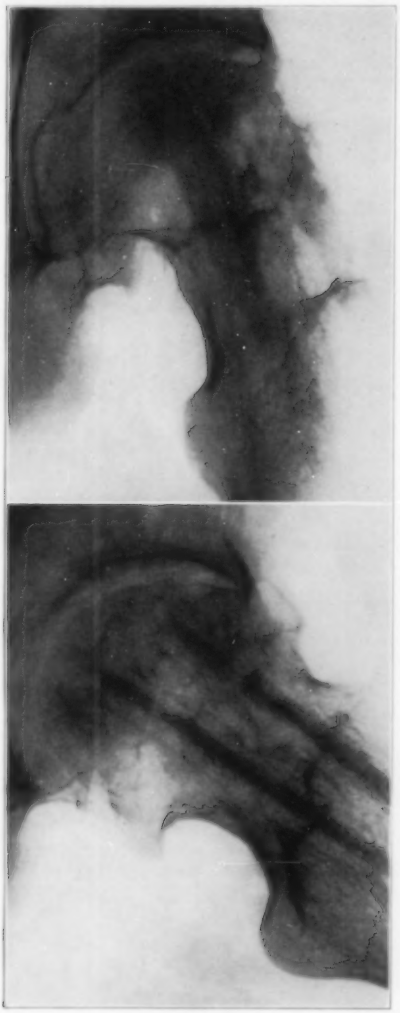

FIG. 6-B

Figs. 6-A and 6-B: Case 7. C. V., a man, twenty-two years old, had had a left femoral-neck fracture treated by Smith-Petersen nailing two and one-half years earlier.

Fig. 6-A: Roentgenograms made prior to removal of the trifin nail, drilling, and bone-grafting show slight depression of the necrotic weight-bearing area of the femoral head.

Fig. 6-B: Complete revascularization without further collapse of the head is apparent in roentgenograms of the hip made two years later.

Four of the seven patients with idiopathic aseptic necrosis had had bilateral disease of two to seven years duration. Each of two patients had cup arthroplasty performed on one hip because of severe collapse of the femoral head with marked degenerative arthritis, and drilling and bone-grafting on the opposite hip. Both patients maintained a satisfactory function of both hips, four years and six and one-half years later. Two patients with bilateral femoral-head necrosis had drilling and bone-pegging of each hip. One of the patients had persistent pain in one hip, secondary to degenerative arthritis, and poor function; cup arthroplasty was performed on the right side three years later. Upon removal of the articular cartilage the femoral head bled freely, indicating revascularization; conservation of femoral-head and neck length was therefore possible. The three remaining pa-

FIG. 7-A

FIG. 7-B

FIG. 7-C

Figs. 7-A through 7-C: Case 9. W. G., a man, thirty-five years old, had had a posterior dislocation of the hip reduced two years earlier.

Fig. 7-A: Roentgenogram made two years after dislocation shows a central area of necrosis in the femoral head.

Fig. 7-B: Marked reduction in density of the central area of necrotic bone was apparent ten and one-half months after insertion of two tibial grafts. Note the grafts projecting to the level of the subchondral cortex.

Fig. 7-C: Roentgenogram made at twenty-seven months demonstrates reossification of this area, slight narrowing of the cartilage shadow, a marginal osteophyte, and increased density of the femoral head.

tients gave a history of specific injury preceding the onset of symptoms but no roentgenograms had been made. That massive necrosis of the femoral head may require more than two drill holes and grafts to repair the femoral head is suggested by the following case:

CASE 10. For seven months, E. R., a male, sixty-one years old, had pain in the right hip accompanied by stiffness and limp. One year before he had bumped his right greater trochanter against the tractor seat when the tractor he was driving hit a hole. The hip was sore for a few days but did not bother him until five months later when he turned over in bed and felt a crack in his hip region. Massive necrosis with fragmentation was evident in roentgenograms of the right hip made at the time of insertion of two tibial-bone grafts. Biopsy of material from

FIG. 8-A

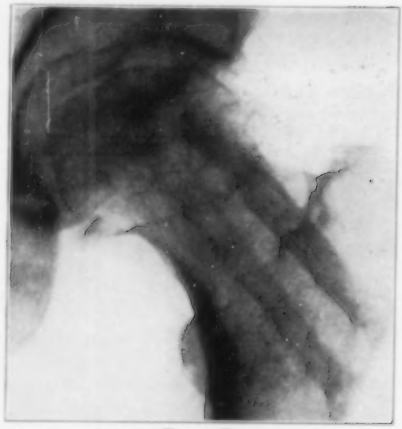

FIG. 8-B

Figs. 8-A through 8-D: Case 11. A. G., a forty-year-old male, was seen two years after an untreated injury to his left hip incurred in an automobile accident.

Fig. 8-A: Roentgenograms of the left hip demonstrate flattening of the femoral head and infraction through the necrotic area.

Fig. 8-B: Six years and five months after surgery the roentgenogram shows an excellent joint shadow, incorporation of the grafts, replacement of the necrotic bone, and minimal arthritic changes.

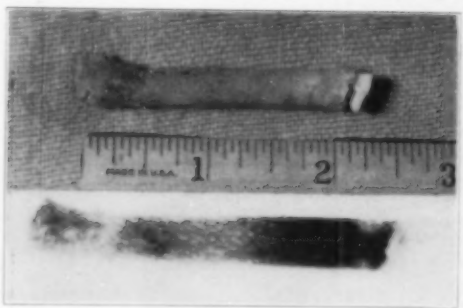

FIG. 8-C

Roentgenogram and a photograph of a core biopsy indicate the extent of necrosis. Note the separated articular cartilage, a frequent finding in femoral-head necrosis.

the femoral head confirmed the diagnois of extensive necrosis with multiple fractures. A low-power photomicrograph revealed necrotic bone and marrow proximal to an area of fragmentation, beneath which there was a zone of thickened trabeculae composed of new bone on old necrotic bone. The articular end showed normal cartilage and necrotic subchondral trabeculae. Roentgenograms made at six months revealed further collapse of the head. The patient was known to have borne full weight on his right lower extremity in spite of instructions to walk with crutches. Five years after surgery, the patient had poor function but only occasional slight pain on motion of the hip. Roentgenograms of the hip at this time showed incongruity of the joint, narrowing of the cartilage shadow, and marginal osteophytes. The patient was satisified and refused further surgery.

An example of an excellent functional result six years and five months after treatment of a necrotic femoral head with minimal collapse is presented in Case 11:

CASE 11. A. G., a forty-year-old male, was seen two years after an untreated injury to his left hip incurred in an automobile accident. He had had pain in his hip on walking, limp, and inability to work for eight months prior to examination. Roentgenograms of the left hip showed flattening of the femoral head and infraction through the necrotic area (Fig. 8-A).

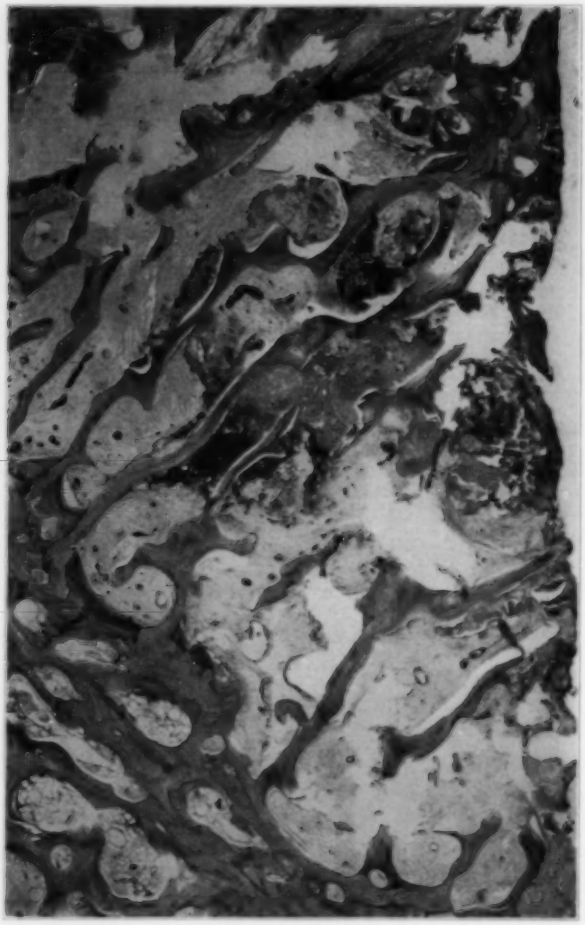

FIG. 8-D

A photomicrograph of a biopsy specimen taken near the subchondral cortex reveals calcified fibrous marrow, dead trabeculae, and new bone on unreplaced trabeculae.

Three areas in the necrotic head and neck were biopsied and tibial transplants inserted in two of the drill holes from the trochanter to the subchondral cortex. A roentgenogram and photograph of the core biopsy indicated the extent of necrosis (Fig. 8-C). (Note separated articular cartilage, a frequent finding in femoral-head necrosis.) Photomicrograph of area near the subchondral cortex revealed calcified fibrous marrow, dead trabeculae, and new bone on unreplaced trabeculae (Fig. 8-D). The patient was on protected weight-bearing for eleven months. Six years and five months after surgery a roentgenogram showed an excellent joint shadow, incorporation of the grafts, replacement of the necrotic bone, and minimal arthritic changes (Fig. 8-B). The patient had no pain or limp, excellent function, and an almost normal range of motion.

COMPLICATIONS

There were no operative deaths. The seven deaths which did occur were from other causes; the earliest at three months after surgery. Infection developed in three patients; a sinus formed after extrusion of a threaded pin in one patient; and an infection developed in two patients after reoperation for failure of the bone graft procedure.

An attempt was made to evaluate the degenerative arthritis of the hip which

developed in most patients. As can be noted in Table III, many of the patients with aseptic necrosis of the femoral head had degenerative changes prior to surgery. It was not possible to correlate the roentgenographic finding of degenerative arthritis with the clinical end result since most of these patients were asymptomatic.

DISCUSSION

The satisfactory results obtained in 75 per cent of the patients operated on by drilling and bone-grafting for aseptic necrosis of the femoral head, with or without union of fractured femoral neck, indicate that this procedure is useful in preserving and restoring the patient's natural femoral head. Some of the unsatisfactory results in this series are those which can be ascribed to preventable causes, most important of which is improper placement of the cortical transplants as to location and depth. In four cases a better execution of the procedure may have altered the outcome. Early weight-bearing before reconstitution of the head and neck contributed to failure in three other patients.

At times poor function may be due to weak musculature about the hip. Several patients overcame fatigue pain and limp, enough to improve their rating by a program of hip muscle strengthening exercises. Another observation of note in the evaluation of these patients is the lack of correlation between hip function and the roentgenographic findings.

The twelve-month time interval required from operation to full weight-bearing in the patients with a necrotic head is of interest. It was anticipated that this period would be much longer, according to previous observations of a four-year period of time required for repair of a necrotic head treated by protected weight-bearing alone.

Markedly restricted range of motion of less than 90 degrees of flexion of the hip in patients with aseptic necrosis is not likely to be improved by bone-grafting. However, it is important to report that four patients in this series were operated upon specifically to revascularize collapsed necrotic femoral-head fragments so that stock could be preserved in preparation for a subsequent cup arthroplasty. Two of these patients are satisfied at present in spite of limited motion in the hip. One patient has had cup arthroplasty. Others (for example, Case 10) may come to some type of reconstructive hip procedure in the future. Therefore, early application of this biological principle of bone-grafting for non-union or aseptic necrosis, or both, should lead to better results. This procedure is now being done at the University Hospitals as soon as roentgenographic evidence of loss of position of fracture fragments, insecure internal fixation, or density changes in the femoral head, indicating aseptic necrosis, occur. The procedure is not advised if the patient is physiologically old or unable to walk with crutches.

SUMMARY AND CONCLUSIONS

An evaluation has been made of the effect of drilling and bone-grafting for non-union of the fractured femoral neck or aseptic necrosis of the femoral head, or both, in fifty-three patients. The results show that the procedure is effective in restoring continuity to the ununited femoral-neck fracture, and viability to the necrotic femoral head in a sufficient number of instances to warrant its consideration in the management of these complications.

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DISCUSSION

DR. SAM W. BANKS, CHICAGO, ILLINOIS: Dr. Dallas B. Phemister stressed the relationship between the early diagnosis and the prognosis in cases of aseptic necrosis of the head of the femur and forms the basis for discussion of this—the major unsolved problem of fractures of the neck of the femur and traumatic dislocations of the hip. In 1947, Dr. Phemister reported the results of five patients treated by his method; he emphasized that it minimized secondary collapse of the dead portion and allowed resumption of weight-bearing earlier than it was possible when the use of crutches was the sole treatment. Dr. Phemister was convinced that the procedure was based on sound observations of the pathological changes in the femoral head and formed a program the average patient could accept from an economic point of view.

No additional report on this operation, to my knowledge, has appeared in the literature and we are, therefore, profoundly grateful to Dr. Bonfiglio and Dr. Bardenstein, as well as their colleagues at the State University of Iowa, who cooperated in this study. It is fortunate that Dr. Bonfiglio found himself at the University of Iowa where in a relatively short period of time, fifty-three patients with aseptic necrosis of the femur were admitted for treatment. It is unlikely that his number of cases could have been accumulated in private practice by a single surgeon.

Most dead femoral heads, in my experience, can be recognized roentgenographically during the first six to eight months of treatment of the acute injury by relative densities and before walking is resumed. When the head is shown to be necrotic, two tibial-bone grafts should be inserted immediately, as pointed out by the authors, in order to hasten restitution and obtain union of the fracture when necessary. Many hips, which otherwise would be doomed to cause pain and produce deformity, can be salvaged effectively as shown by the results reported.

The operation rarely causes shock and it can be performed with safety on the older individual. Although it is easier to obtain than tibial-bone grafts, in my opinion fibular bone should not be used. Its dense cortical structure does not stimulate rapid replacement of the dead head and frequently the proximal portion of the graft separates off as a sequestrum preventing final restitution of the head and increasing the collapse of the summit.

The Phemister operation is preferable to replacement or cup arthroplasty as treatment of aseptic necrosis when the diagnosis is established and before irreparable damage to the femoral head has occurred.

I would like to ask the authors whether they would recommend the Phemister operation for the primary treatment of all acute fractures of the femoral neck in view of the 35 per cent incidence of necrosis, half of which failed to heal. The healing time would likely be diminished in all cases, non-unions minimized, and the reparative process would be established at once in instances of necrosis, thereby materially decreasing the time of total disability.

DR. BONFIGLIO (closing): The question as to whether we would consider using this procedure in fresh fractures of the neck of the femur was asked. This has been done as most of you know. King, in 1939, reported a series of primary grafting operations for fractures of the neck of the femur, and his incidence of union was about 70 to 75 per cent in fresh fractures.

About ten years ago another surgeon I know, Dr. O'Donoghue of Sioux City, had a series of a hundred consecutive fractures of the neck of the femur in which he performed a delayed bone-grafting procedure on each patient. A nail and two threaded pins were inserted at the time of injury, and then, three weeks later the nail which was put in the dead center area was removed and substituted with a graft. The incidence of union was 90 per cent by his technique, but his follow-up was only one year.

In general, we believe that we should not penalize the 70 per cent who don't get massive necrosis of the head following fracture by a primary grafting. I think all of us should learn to recognize when failure is going to occur from primary treatment with nail or pins, or whatever method you use for treatment of the fractured neck of the femur, and then immediately employ the most effective therapy for that situation. If it is aseptic necrosis, non-union, or both, we will continue to do bone grafts as long as they produce such good results as they have done so far. We have not burned any bridges by doing this procedure.

We can still insert a prosthesis if this fails or we can still do cup arthroplasty.

The Dashboard Femoral Fracture

Pathomechanics, Treatment, and Prevention *

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Injuries sustained in high-speed automobile accidents present multiple complicated diagnostic and therapeutic problems for both civilian and military practitioners. The dashboard femoral fracture and its associated injuries are unique to automobile travel. This type of injury will undoubtedly become more common with increased crowding of highways, the lack of safety features in automobiles and the highway itself, and the apathy of the public toward these problems.

Between January 1951 and April 1957, a total of 263 femoral-shaft fractures were treated at Walter Reed Army Hospital. Fifty-two of these were closed comminuted fractures of the shaft incurred in automobile accidents. Of these, nineteen were typical dashboard femoral fractures; the remainder of the group of fifty-two were angulation or torsion fractures with secondary minor comminution. Thus, 7.2 per cent of all femoral fractures in this series were of the dashboard impaction type. Eleven consecutive case reports collected by the senior author were added to bring the total number presented in this series to thirty.

PATHOMECHANICS

There are four types of femoral-shaft fractures classified as to the force encountered. Any one of these can be sustained in an automobile accident, depending upon the type and magnitude of force applied to the femoral shaft at the time of injury. The angulation fracture is caused by a perpendicular force applied to the shaft with a resultant transverse fracture line, with or without a third triangular fragment.

The torsion fracture, as the name implies, is secondary to a torsional strain applied to the shaft. The resultant fracture is typically a long spiral or an obliquely spiral fracture, with or without small comminuted fragments at the ends of the fracture line.

The missile fracture is an open fracture; the bone damage, to a large degree, depends on the size and velocity of the missile. Low-velocity missiles produce mild comminution; high-velocity missiles produce explosive comminution accompanied by scattering of fragments throughout the adjacent soft tissue.

The fourth type is represented by the impaction fracture and is usually seen in cancellous bone, such as the vertebral bodies, the os calcis, and the tibial plateau. In these fractures, substantial force in longitudinal compression is necessary to cause failure of structural bone. An extreme expenditure of energy is required when the femoral shaft, the strongest bone in the body, is shattered in a similar manner. The modern automobile has such potential force, and when applied along the longitudinal axis of the femur this force can cause extensive comminution over a large area of the shaft. This fracture configuration is characteristic and cannot easily be confused with the types previously described (Fig. 1).

*Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, New York, N. Y., February 4, 1958.

FIG. 1
Impaction fracture.

The femoral-shaft fracture is peculiar to the driver or front-seat automobile passenger traveling at high speeds. In the usual sitting posture, the femoral shaft is parallel to the major line of force, with the patella and upper portion of the tibia facing the dashboard. During a head-on collision, with its resultant rapid deceleration, the front-seat occupants continue directly forward and the knee region strikes the instrument panel or floorboard (Fig. 2). The upper por-

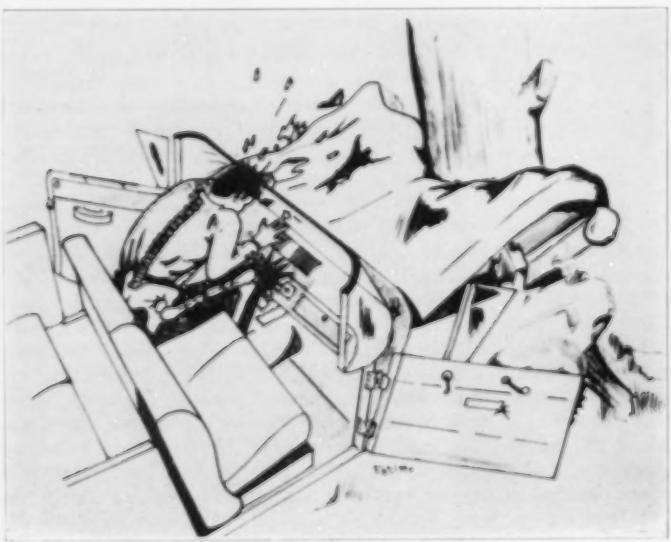

FIG. 2
Pathomechanics of the dashboard femoral-shaft fracture.

tion of the torso is then jackknifed downward and forward with hip flexion, to strike the head and chest against the steering wheel, the top of the dashboard, or the windshield. This well recognized pattern was previously reported, but usually in association with dislocations of the hip[6,8,16], patellar fractures[13], and maxillofacial injuries[14,15]. Woodward, however, in his classic criticism of the modern automobile, briefly illustrated this type of femoral fracture and a more recent symposium[9] presented an example of this specific injury.

As Kulowski[10] stated, we are dealing with tremendous force energized by distance. Computations indicate that a two-hundred-pound passenger with his knee two inches from the impact object, decelerating totally from sixty miles per hour, may have a force of fifty tons or more applied to the longitudinal axis of the femoral shaft. A recent paper by Bechtol points out the brittle nature of

FIG. 3

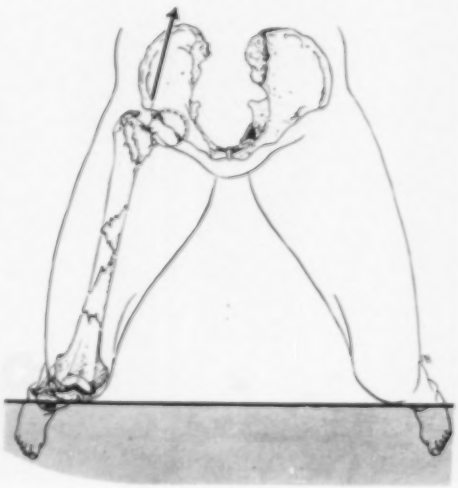

FIG. 4

Fig. 3: Posture of the hip in adduction. Dislocation results on longitudinal force-application to the femur.

Fig. 4: Posture of the hip abduction. The femoral head cannot escape from the acetabulum and femoral fracture may occur.

bone and the fact that compressive forces applied along the longitudinal axis of long bones cause shattering and severe comminution due to failure of the trabecular pattern. The studies of Evans, Pedersen, and Lissner and Lissner and Evans have borne this out and have further shown that dynamic loading of the femur with relatively small forces can cause failure, with resultant fracture. Unfortunately, these experiments did not include dynamic femoral loading from the distal end, in the direct anatomical axis of the femoral shaft, as occurs in this injury.

If the passenger's hip is adducted, the femoral head is well out of the acetabulum, and posterior dislocation of the hip results from the impact of the knee against the dashboard (Fig. 3). This appears to be the usual injury to the female passenger who habitually rides in automobiles with the hips adducted. Dislocation of the hip in the female passenger, therefore, is not unusual, but the dashboard femoral fracture is rare; there was none in this series. The usual posture of the male in the front seat, especially if he is driving or is a sleeping passenger, is that of wide hip abduction, with the femoral head well seated in the acetabulum and with the greater trochanter riding almost against the ilium postero-inferiorly

(Fig. 4). With the hip in abduction, dislocation cannot occur, and, femoral fracture results. Associated acetabular or femoral-neck fracture may also be sustained. The impact area is the knee region, which usually is extremely resilient and tolerant of trauma. In this traumatic syndrome, part of the decelerative force is absorbed by the knee with a varying amount of local injury, but the major force is transmitted to the femoral shaft. Basically, therefore, this fracture results from instantaneous longitudinal compression of the femoral shaft by extraordinary force, resulting in structural failure of the shaft over a long area, with extreme fracture comminution.

In an analysis of the pathomechanics in this series of thirty it was found that

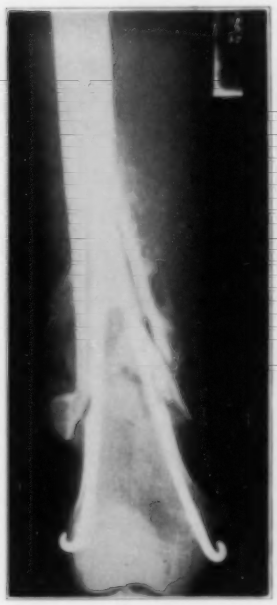

FIG. 5

FIG. 6-A

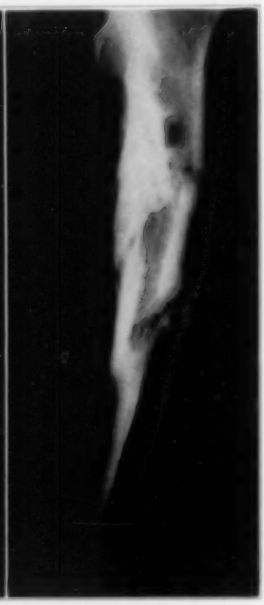

FIG. 6-B

Fig. 5: Internal fixation attempted with multiple fixation devices.
Fig. 6-A: Case 5. Original dashboard femoral fracture.
Fig. 6-B: Eleven months after fracture. Skeletal traction was used for three months.

all patients were front-seat occupants. Thirteen were drivers, nine were sitting in the right front seat, one was seated in the front middle seat, and seven were front-seat occupants, but their exact location is unknown. All were males, and none was wearing a seat belt. Twenty-four patients observed, or questioned directly, by the authors, verified impact injury to the knee, by either history, evidence of laceration, contusion, or definite structural knee damage. Ten patients actually stated that the injury was caused by the knee striking the instrument panel.

Further study of the thirty accidents revealed that twelve occurred as a result of a head-on collision with another moving vehicle. Seventeen were the result of an impact with fixed roadside objects—trees or utility poles in fourteen instances, and a bridge or grade abuttment in three. In one case the impact object was unknown. All of those striking a non-moving object admitted to speeds of over forty-five miles per hour. The maximum admitted speed was ninety miles per hour and the average admitted speed was sixty miles per hour. In the twelve head-on collisions with other vehicles the admitted speed was somewhat lower.

Clinical Features

The time-honored rule of treating the patient as a whole and not as an isolated injury is applicable here. The dramatic roentgenographic aspect of the comminuted femoral-shaft fracture, of course, will first draw the observer's attention. The hip or knee may not even appear on the initial film, and even if it does, a small acetabular fracture or knee injury may be overlooked by the unwary. These associated injuries at the hip and knee, however, frequently cause more residual disability than the femoral fracture itself and care must be taken not to overlook these less apparent injuries.

All thirty patients in this series had moderately to severely comminuted fractures of the femoral shaft; distribution was about equal between the left and the right femur. There were four patients who also exhibited contralateral femoral-shaft fractures. In each instance these were of the transverse angulation type with minimal or no comminution.

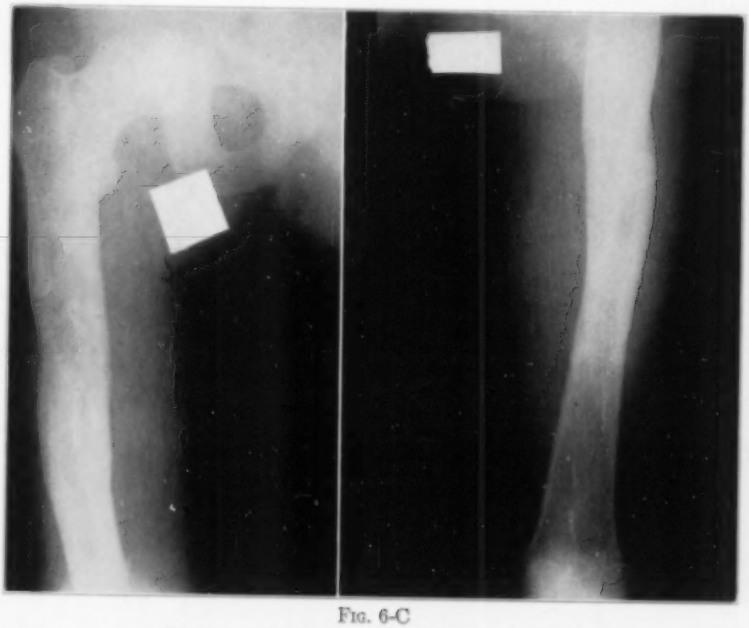

FIG. 6-C

Five years after fracture. No disability is present.

Definite ipsilateral knee injury was recorded or observed directly in twenty-four patients (80 per cent) of the series. The telltale contusions or lacerations about the knee at the site of the impact are important clinical diagnostic signs; they may overlie severe structural damage. The patella may be compressed against the femoral condyles and a transverse or comminuted fracture of the patella may be sustained, as was the case in three patients in this series (Cases 7, 23, and 24). If the knee is acutely flexed, the major damage may be confined to the unprotected femoral condyles. The femoral articular surfaces, however, may be considered as always being injured, but this may or may not be apparent on examination. When the upper portion of the tibia sustains the impact, its posterior displacement on the femur may cause rupture of the posterior cruciate ligament. This occurred in three patients (Cases 3, 15, and 21). If the major impact is sustained by the upper portion of the tibia, complete disruption of the knee may result. One patient had tears of both cruciate ligaments, the medial collateral ligament, and the medial meniscus (Case 16); one sustained a lateral

TABLE I

GROUP TREATED BY THE CLOSED METHOD

Case	Follow-up (*Months*)	Time in Traction (*Months*)	Unprotected Ambulation (*Months after injury*)	Complications	Residual Disabilities			Comments (*Months after Injury*)	Results
					Femur (*Shortening in Inches*)	Hip	Knee		
1	24	3	9	None	None	None	None	Duty, 8	Excellent
2	13	10	13	None	¼	None	None	Duty, 13	Excellent
3	60	5	8	None	1	Traumatic arthritis	Unstable, pain, movement from 135 degrees to 45 degrees	Medical discharge, 12	Poor
4	60	4	6	None	1½	None	None	Duty, 6½	Poor
5	66	3	11	None	None	None	None	Duty, 11	Excellent
6	48	4	12	None	1	Slight pain	Pain, movement from 180 degrees to 85 degrees	Duty, 11	Fair
7	12	5	8	Renal calculus	Amputation, contralateral	None	Movement from 180 degrees to 160 degrees	Medical discharge, 12, for amputation	Fair
8	96	1 Spica, 4	Never, union, 7	None	5½	None	Movement from 180 degrees to 135 degrees	Medical discharge, 14	Poor
9	18	6	12	None	None	None	None	Medical discharge, 18, for other injuries	Excellent
10	9	5	8	None	¼	None	None	Duty, 9	Excellent
11	36	5	23	None	None	None	None	Medical discharge, 12, for other injuries	Excellent
12	24	3	5	None	¾	None	None	Duty, 5	Fair
13	14	3½	7	None	None	None	None	Duty, 10	Excellent
14	18	4	11	Delayed union graft, 4 months after injury	1	None	Pain	Duty, 8	Fair

TABLE II

GROUP TREATED BY THE OPEN METHOD

Case	Follow-up (*Months*)	Method	Unprotected Ambulation (*Months*)	Complications	Residual Disabilities: Femur (*Shortening in Inches*)	Residual Disabilities: Hip	Residual Disabilities: Knee	Comments (*Months after Injury*)	Results
15	12	6-hole plate and iliac graft	None 8, to union	Osteomyelitis, sequestration, and bone loss	¼ infection and bone loss	None	Unstable	Medical discharge, 12	Poor
16	6	Küntscher nail	5	None	1½	None	Unstable, pain	Duty, 6	Poor
17	19	Küntscher nail, wire loops	None at 19	Osteomyelitis and sequestration	2¼	None	Movement from 180 degrees to 165 degrees, pain	Medical discharge, 19	Poor
18	24	Küntscher nail	12	Osteomyelitis and sequestration	½	None	Movement from 180 degrees to 90 degrees, pain	Medical discharge, 13	Poor
19	9	6-hole plate	None, union 9	Screws broke	1¼	None	None	Duty, 9	Fair
20	72	Two 6-hole plates and bone graft; Küntscher nail and graft, 15	18	Pulmonary emboli, osteomyelitis, and non-union	¼	None	Movement from 180 degrees to 90 degrees, pain	Medical discharge, 19	Poor
21	9	Rush rod, screw, and wire loops	8	None	¼	None	Unstable, movement from 175 degrees to 120 degrees	Duty, 9	Poor
22	48	2 screws	8	None	1	None	None	Duty, 9	Fair
23	10	2 Rush rods	7	None	1½	None	None	Medical discharge, 10	Poor
24	96	6-hole plate and iliac graft	18	None	1½	Severe arthritis	Pain, movement from 180 degrees to 90 degrees	Medical discharge, 14	Poor
25	24	6-hole plate and 3 screws	13	Delayed union, secondary graft and Küntscher nail	¾	None	None	Medical discharge, 24, for other injuries	Fair
26	34	Küntscher nail, 4 wire loops	4	None	None	None	None	Duty, 5	Excellent
27	36	Rush rods, two 6-hole plates	15	Thrombophlebitis	1½	None	Pain, movement from 180 degrees to 90 degrees	Medical discharge, 18	Poor
28	9	Küntscher nail, 2 loops	8	Serum hepatitis	¾	None	None	Duty, 9	Fair
29	24	Küntscher nail	7	None	¾	None	None	Medical discharge, 12, for other injuries	Fair
30	22	Küntscher nail, wire loop	15	None	Distal amputation	None	Pain, movement from 180 degrees to 90 degrees	Medical discharge, 22, for amputation	Good

collateral ligament tear (Case 17), and two cases of fracture about the upper portion of the tibia and fibula were also recorded (Cases 6 and 18). All of these injuries may of course be open. There were fourteen patients with abrasions, contusions, and lacerations, only about the knee. It should be noted that even if none of the structural injuries of the knee are incurred, as was the case in six patients, and in spite of the natural ability of the knee to resist injury, definite damage to the area probably is incurred in each instance. Smillie pointed out that tremendous force applied to the knee during dashboard impaction will cause brawny oedema of the surrounding soft tissue, fibrosis and thickening of the anterior capsule, and later, resultant limitation of flexion. Evaluation of the end results revealed residual knee symptoms in fourteen patients.

Analysis of the thirty cases (Tables I and II) showed that six patients (20 per cent) had associated injury about the hip on the same side as the femoral fracture. Four patients sustained comminuted fractures of the acetabulum (Cases 3, 7, 9, and 24), one of the femoral neck (Case 6), and one patient had an impaction fracture of the greater trochanter (Case 22). The mechanism of these fractures results from the same energy application as the shaft fracture and must occur simultaneously with it, the force being transmitted to the femoral neck, head, and acetabulum. Final evaluation revealed residual hip symptoms in three of these patients (Tables I and II).

Other regional injuries were predominantly to the face and skull secondary to jackknife flexion at the hips, which drove the head down and forward against the upper part of the dashboard or the windshield. Six maxillary facial fractures, one skull fracture, and three severe facial lacerations were sustained. These were associated with varying degrees of cerebral concussion. Next in incidence were forearm fractures followed by a large and diverse group of multiple and miscellaneous injuries.

TREATMENT AND RESULTS

Discussion is primarily confined to the femoral-shaft fracture. Many different surgeons with varied experience were responsible for the initial stages of treatment in 90 per cent of this group. These patients, however, sooner or later arrived at a specialized orthopaedic center. In this series, fourteen patients were treated by closed methods (Table I) and sixteen patients were treated by open reduction with varied forms of internal fixation (Table II). The average follow-up period for the group treated by the closed method was thirty-six months while that for the group treated by open methods was twenty-eight months.

Skeletal traction was the primary mode of treatment in the closed method group. However, in one patient in this group (Case 8) a plaster spica was applied after only one month of traction. The average time in traction for these patients was 4.6 months and the time to unprotected weight-bearing averaged ten months from the time of injury. Two instances of complications occurred in this group, neither contributing to the end result. In one patient, a renal calculus developed (Case 7), and a second patient (Case 14), at the end of four months of traction, was judged to have a delayed union of the femur. An iliac-reinforcement graft was inserted and healing then progressed normally and unprotected weight-bearing was resumed at approximately the average time for this group.

The patients in the group treated by surgery were managed by many different methods and with a varied and large assortment of internal fixation devices. Medullary nailing was used in seven, and in four of these, wire loops were added. Plates and screws were used in five patients and screws only were used in one. Rush rods alone, or in combination with wire, screws, or plates, were used in three instances. The average time before unprotected weight-bearing was allowed in this group was eleven months, one month longer than with closed methods. The complication rate was a formidable 56 per cent and complications were more serious (Tables I and II). There were four instances of

postoperative osteomyelitis (Cases 15, 17, 18, and 20), contributing to a poor end result; in one of these patients also multiple pulmonary emboli developed. Further complications consisted of the breaking of the screws holding a plate in one patient (Case 19), one delayed union (Case 25), thrombophlebitis (Case 27), and serum hepatitis (Case 28).

In evaluating the end results of treatment, an arbitrary grading system was devised (Tables I and II). Shortening of the extremity of one fourth of an inch or less without hip or knee sequelae was considered an excellent result; shortening from one fourth of an inch to three fourths of an inch, a good result; shortening of three fourths of an inch to one and one half inches, a fair result; and one and one half inches or more of shortening was considered poor. Cases were further excluded from both the excellent or good groups if there was residual knee instability, moderate pain or limitation of motion, or symptoms secondary to traumatic arthritis of the hip. All cases of chronic osteomyelitis or non-union were placed in the poor group.

Comparison of end results revealed seven excellent, four fair, and three poor results, or 50 per cent excellent results in the group treated by closed methods as compared with one excellent, one good, five fair, and nine poor results, or 6 per cent excellent results in the group treated by open methods. Analysis of the patients treated in skeletal traction revealed that less than excellent results were due to only two factors—the original associated injuries at the hip and knee, and failure to maintain femoral length in traction. No instance of permanently impaired knee motion could be attributed to this closed method of treatment.

Study of the group treated by open method revealed that the poor end results were primarily due to complications arising from operative intervention and to shortening of the femur not controlled by internal fixation. Furthermore, in the group treated by closed methods, only two patients were kept from returning to military duty by the sequelae of their femoral fracture, hip, or knee injury. In the open management group seven patients were discharged from military service because of disability related to the dashboard femoral fracture.

As can be seen, these fractures rarely lend themselves to methods of open reduction and fixation. Heroic exposure of long areas of the femoral shaft is required, with manipulation of many fragments. This in itself is not advisable, and certainly more than a generous amount of fixation material is needed to reassemble these multiple fragments (Fig. 5). The incidence of wound infection is high and frequently results in osteomyelitis. Even barring this catastrophe, fracture-healing is delayed by such extensive surgery. Furthermore, no method of known internal fixation could allow safe early mobilization and ambulation in the face of this amount of comminution, nor would it prevent shortening.

Skeletal traction, therefore, is the apparent method of choice (Figs. 6-A, 6-B, and 6-C). Before the institution of traction applied to the upper portion of the tibial crest, the integrity of the knee joint must be assured by clinical and roentgenographic examination. If there is bony, ligamentous, or extensive soft-tissue injury about the knee, supracondylar femoral traction should be elected. Maintaining traction through disrupted knee ligaments is unsound and will certainly result in knee disability when walking is resumed. The traction requires vigilance in maintaining femoral length; daily bedside measurement should be performed and traction must be continued until healing is advanced to the point where shortening will not occur. As noted in Case 8, one month of traction, followed by plaster immobilization, was not sufficient to maintain length; disastrous shortening resulted.

Various hip and knee injuries associated with the femoral fracture present difficult problems. The single case of femoral-neck fracture associated with ipsilateral shaft fracture was treated successfully with a Smith-Petersen nail and Thornton plate followed by supracondylar traction of the femur for four months

FIG. 7-A

Case 6. Typical dashboard femoral fracture.

FIG. 7-B

Associated femoral-neck fracture.

FIG. 7-C

FIG. 7-D

Fig. 7-C: Fracture avulsion of tibial spines.

Fig. 7-D: Seven months after injury. Femoral-neck fracture is healed; Smith-Petersen nail has been removed.

(Figs. 7-A through 7-D). The associated acetabular fracture, if present, is often best managed by the skeletal traction utilized for the femoral fracture. The femoral fracture should not be considered a contra-indication to open repair of disrupted knee ligaments or acetabulum, but surgery must be followed by supracondylar femoral traction.

PREVENTION

It has been estimated[12] that approximately 50 per cent of all new cars will be involved in a major collision during their useful lifetime. Human nature being what it is, accidents are not preventable. The only solution, then, is to engineer the automobile and highways for safety of the passengers under accident conditions.

The major problem is to dissipate energy to areas other than the knees or head. Furthermore, the occupants should be securely held in their seats. The automobile seat belt performs some of these duties well. In many instances, however, it will accentuate the jackknife effect noted previously. An ideal solution would be to add a shoulder harness, but the task of educating the public in its use would be tremendous. Campbell[3,4], Gibbens, and Braunstein, in recent reviews, emphasized the advantages of automobile seat belts.

Further safety design is necessary, since merely equipping cars with seat belts is no assurance that the occupants will wear them. Shock absorbing bumpers, as suggested by Woodward, a progressively disintegrating frame and energy-absorbing construction of parts in order to increase the time of deceleration, as illustrated by Wenger, and better dashboard design, would also reduce the incidence of this as well as other types of severe injuries. The instrument panel, as we know it, leaves much to be desired. Dashboard padding in our present automobiles is a step in the right direction, but this padding is far too thin and does not cover enough of the surface. A small, resilient, light metal panel with four inches of space behind it and padded with four inches of plastic foam in front, as suggested by Campbell[4], would add eight valuable inches for deceleration. All levers and knobs, of course, should be fully recessed. Various forms of break-away and spring-mounted dashboards have also been suggested. These changes are mechanically feasible, would not add materially to the cost of automobile construction, and would aid considerably in the prevention of dashboard injuries.

As was noted, almost half of the accidents were the result of a head-on collision with a roadside tree or pole. This indicates that highway design, in many instances, could be improved by the elimination of these roadside hazards. Low shrubbery planted at the roadside approaches to bridge abuttments would help to decelerate the vehicle gradually before it reached such an impact object. Furthermore, the twelve instances of head-on collision with another vehicle could have been prevented or the intensity lessened by widely divided dual-highways with interposed shrubbery.

SUMMARY

The dashboard femoral fracture is an injury unique to high-speed automobile accidents. Thirty fractures of this type are reported, analyzed, and evaluated as to end result. The fracture conformation is characteristic and the etiological forces are constant. Great care must be exercised so that hip and knee injuries, associated with obvious shaft fracture of this type, will not be overlooked.

The femoral-shaft fracture is best managed conservatively in skeletal traction with constant supervision to prevent femoral shortening. Open surgical treatment of associated ligament tears of the knee and femoral-neck fractures is recommended, but this surgery does not alter the indication for conservatism in management of the femoral-shaft fracture. In spite of the magnitude of this injury, favorable results can be anticipated, in a reasonable period of time, with conservative management.

Prevention of this injury requires safety engineering of automobiles and highways. Proper construction of the instrument panel and the installation of seat belts to allow controlled deceleration on impact are both feasible and economical. The wearing of seat belts will specifically prevent dashboard injury to the femur, knee, and hip, but on jackknifing, will not prevent other associated

injuries. The removal of roadside impact objects, the construction of widely separated dual-highways, and the planting of the low roadside shrubbery are recommended to reduce the number of head-on collisions, which cause so many highway deaths, as well as this formidable dashboard injury.

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The Correction of Equinus Deformity in Cerebral Palsy*†

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The value of orthopaedic surgery in the care of patients with cerebral palsy has been a matter of discussion for many years and, indeed, has been the subject of considerable controversy. Experiences with these procedures in the hands of some have been such as to cast disfavor on many of them and upon the value of surgery in treatment.

For many years now, orthopaedic surgical procedures have been performed in considerable volume on patients with cerebral palsy at the Children's Hospital. A previous report included the period 1925 to 1940[2]. During the last three years a detailed follow-up was made of patients with cerebral palsy treated by orthopaedic surgery in the period 1940 to 1954. This evaluation is still continuing. In this period of time over 650 operative procedures were performed on over 200 patients. This report will cover only one aspect of this study —the correction of equinus deformity. It is our purpose to evaluate the results of such surgery and to analyze the factors which contribute to the results. Subsequent papers will report on the evaluation of procedures designed to correct other deformities.

During the period 1940 to 1954, 153 patients were operated upon to correct equinus deformity. Of these patients, 106 were recently seen and evaluated in a follow-up clinic. Sufficient data were available in the records of twenty-six additional patients to determine adequately the end result of their surgical procedures, although the patients were not seen in the follow-up clinic during the recent evaluation. There were no data available for end-result study in twenty-one patients. A total of 132 patients will therefore be reported in this paper.

All of the patients reported on were seen more than two years after their operations, the average being seven years. Seventy-one of these patients were seen more than five years after operation, of whom thirty-two were seen more than ten years after operation. All patients had spastic cerebral palsy; two had athetosis as well. All were under fourteen years of age at the time of surgery, and forty-one were less than five. The youngest patient was two years and ten months old. There were eighty males and forty-four females. There were five instances of monoplegia, fifty-five of hemiplegia, nineteen of paraplegia, and fifty-three of quadriplegia.

ETIOLOGY

Of the 132 patients reported on, data were available in 112 for evaluation of etiology. In thirty-nine patients there was a history of a normal period of gestation and a normal labor, delivery, and neonatal period. A history of premature birth was present in fifty-eight patients. Two patients presented a history of familial spastic paraplegia. Exceedingly long periods of labor with difficult deliveries and resuscitation were reported in fourteen patients. It should

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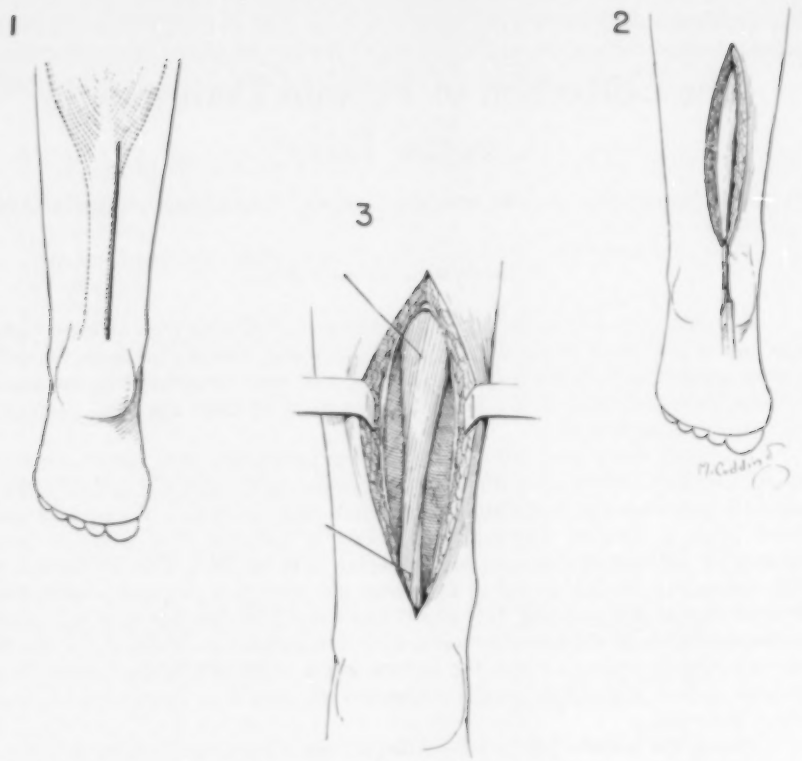

FIG. 1-A

The skin incision is medial in position. The incision of the subcutaneous tissues is carried directly through the tendon sheath so that the sheath can be reconstructed effectively. The rotation of the fibers is carefully identified so that one half can be divided above and one half below.

be noted that 52 per cent of those for whom the term of gestation was recorded were premature, and that 12.5 per cent of the births in which information was available regarding labor and delivery were described as difficult or by instruments.

MENTAL STATUS

Fifty-one of the patients were considered to be of normal mentality. Sixty-two were definitely retarded, including eighteen patients who were classified as severely retarded or feeble-minded. The latter patients had intelligence quotients of fifty or less. No data were available regarding the mentality of the remaining nineteen patients.

INDICATIONS FOR SURGERY

The surgical correction of equinus deformity was considered to be indicated if a tip-toe or toe-heel gait persisted for what was considered to be an adequate period of conservative treatment which included such measures as stretching and active exercises, gait training, night casts, and braces. The position of the foot in stance and the overactivity of the gastrocnemius and soleus in walking were the guiding factors in the decision. The fact that the foot in a relaxed state could be pushed by heavy pressure to a right angle was in no way a contra-indication to surgery.

Necessarily the patient had to have the potentiality of walking before any surgical procedure in the foot was considered. Good balance in sitting and standing was considered essential. Thirty-one patients were not walking without support before surgery.

Procedures in the foot were not performed until postoperative cooperation could be expected. In this series this was not below three years of age. A resistant fixed deformity was an indication for surgery at an early age if the child was intelligent. In those mentally retarded, the age of the patient at the time of surgery was ordinarily older. Retardation was not a contra-indication to surgery if the child could be made ambulatory.

In these 132 patients, 224 operative procedures were performed. These included 164 heel-cord lengthenings, nineteen fractional lengthenings of the gastrocnemius, seventeen Stoeffel neurectomies of the nerve to the gastrocnemius, and twenty-four triple arthrodeses.

HEEL-CORD LENGTHENINGS

In 112 patients, 164 heel-cord lengthenings were performed. These included 133 of the sliding type and thirty-one Z-plasty or miscellaneous varieties. In forty-nine instances, bilateral heel-cord lengthenings were performed. In three patients, a secondary heel-cord lengthening was performed after a previous

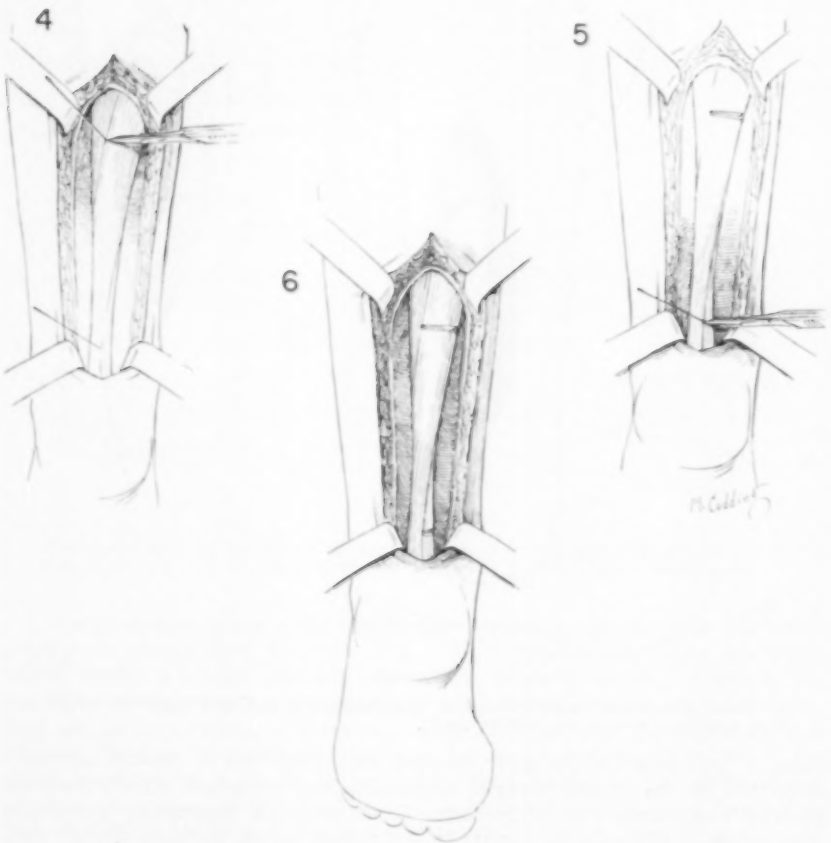

FIG. 1-B

The tendon is then incised at two levels observing the rotation of the fibers. A third incision mid-way between the others is occasionally indicated.

procedure at another hospital. In these patients it was not possible to do a sliding lengthening and, therefore, a Z-plasty was performed.

In one patient, a secondary lengthening was done bilaterally. On review of this patient's record, there is some question as to the necessity for this secondary procedure. Another patient was operated on elsewhere after his original sliding lengthening at this hospital. A transcript of his record also raises some question as to the advisability of this inasmuch as he was considered to have chronic poliomyelitis and his foot was described as coming to neutral dorsiflexion without much difficulty. Seven heel-cord lengthenings were performed in four patients after previous neurectomies associated with fractional length-

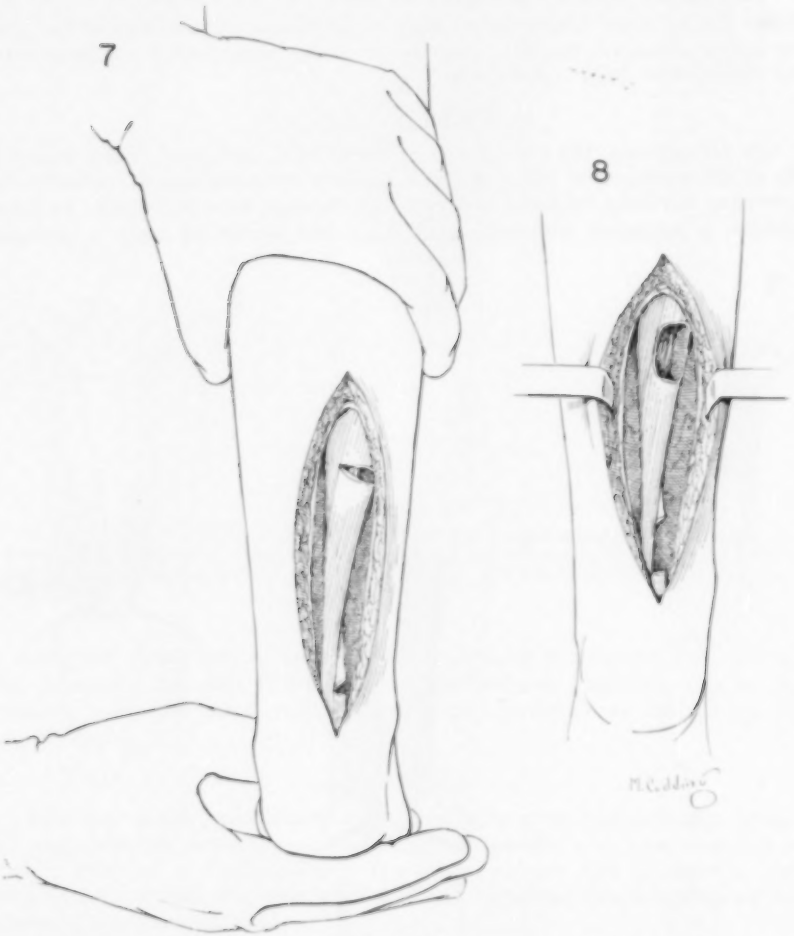

FIG. 1-C

Passive dorsiflexion results in a sliding lengthening with so firm a continuity of the heel cord that sutures are seldom used[5].

ening of both heads of the gastrocnemius were found not to provide adequate correction. In one patient bilateral lengthening was performed after a previous bilateral neurectomy was unsuccessful. Seven heel-cord lengthening procedures were followed subsequently by triple arthrodeses in six patients. These were usually done for a varus or valgus deformity of the foot, but all had some residual equinus deformity after the lengthening procedure; the arthrodesis was patterned so as to correct the equinus deformity.

The procedure most commonly used is the so-called sliding type. The technique employed (Figs. 1-A, 1-B, 1-C, and 1-D) has been used by one of us for many years now at the Children's Hospital and is similar to that which has been described by White. The operation is performed with the patient in the prone position. A posterior incision just medial to the heel cord and about three inches in length is made (Fig. 1-A). The incision is developed sharply and in one plane directly down to the tendon. Its thin, flimsy sheath is thus incised so that it reflects in one layer still attached to the subcutaneous tissues. No additional dissection around the sheath and beneath the tendon is necessary.

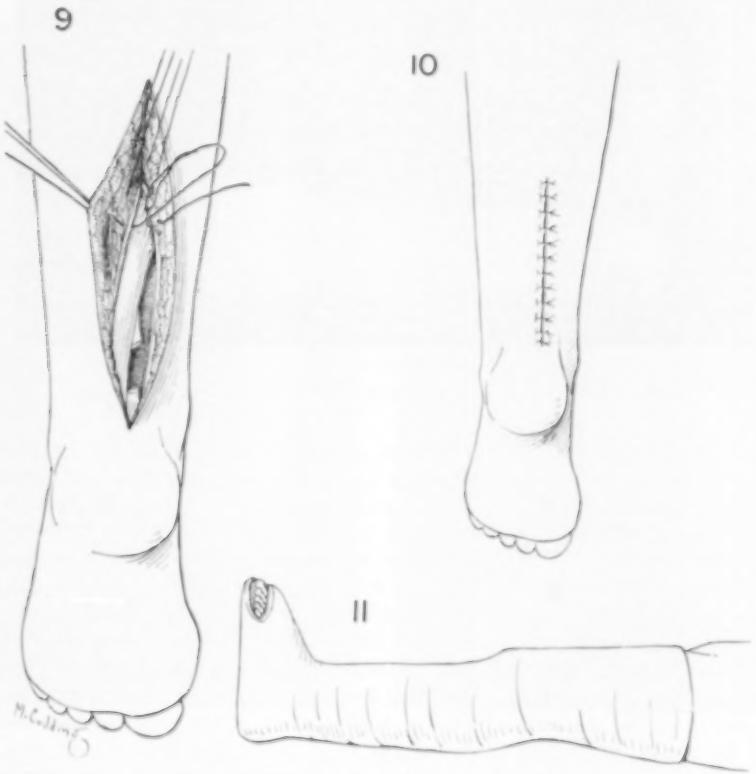

FIG. 1-D

The sheath must be closed over the lengthened tendon. The limb is immobilized with a toe-to-groin cast with the knee in extension and the foot in neutral dorsiflexion.

The procedure takes advantage of the rotation of the fibers of the tendo achillis. As viewed from the back (Fig. 1-A) it may be seen that those fibers which occupy a medial position above twist laterally as they approach the calcaneus so that they are then posterior to those fibers which originally occupied the lateral position. A transverse division is made of approximately half of these fibers in the proximal portion of the wound and the other half in the distal portion (Fig. 1-B). In practice, the fibers divided in the proximal end are those posteromedial and those divided in the distal position are anteromedial. The amount of rotation of the fibers varies and the sites of division must be chosen accordingly. When the divisions have been performed, as illustrated in the diagram (Fig. 1-C), the foot should then be passively dorsiflexed strongly with the knee in extension. A sliding of the medial on the lateral fibers of the

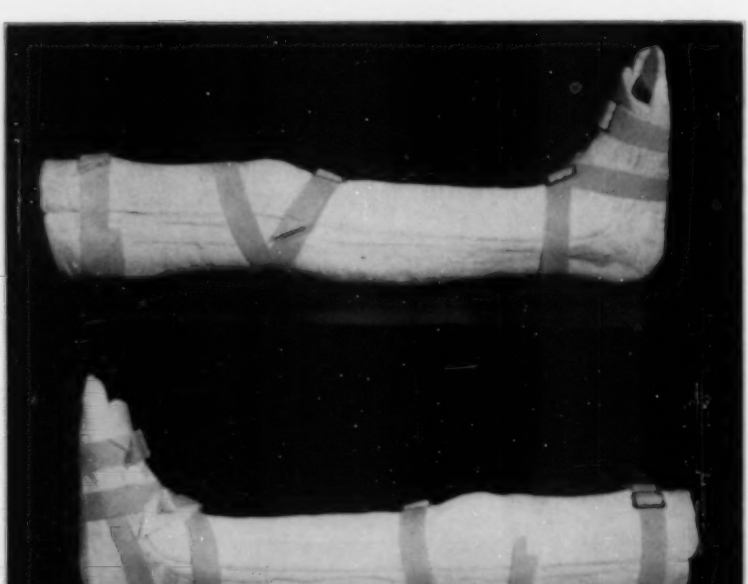

FIG. 2

Bivalved removable cast used postoperatively to maintain correction.

tendo achillis then occurs, resulting in an actual lengthening of the tendon in continuity. If sliding does not occur easily, the sites for additional division can be recognized visually and by palpation. Passive dorsiflexion should be done to result in a sliding lengthening which allows the foot to rest comfortably in a neutral position. Correction beyond this point may result in a calcaneus deformity postoperatively. This type of lengthening does not give rise to fraying of the tendon as in the Z-plasty. The tendon is so firm in contact and has enough tensile strength that suture is not essential but may be performed at the discretion of the surgeon. There is ordinarily firm continuity of the tendon at the end of the procedure. The wound is then closed. It is important to suture the sheath of the tendon, including a small portion of the subcutaneous tissues over the newly lengthened tendo achillis (Fig. 1-D). The limb should then be immobilized in a toe-to-groin plaster cast, adequately padded, with the knee fully extended and the foot at 90 degrees of dorsiflexion. The lengthening performed in the patients included in this report followed these general principles, but inasmuch as they were performed by many different surgeons, there was considerable variation in technique.

To obtain a good result the postoperative care of these patients must be very carefully and patiently supervised. Naturally, in a large series of patients the postoperative care will vary somewhat. However, the typical patient, after a sliding heel-cord lengthening, was immobilized with a toe-to-groin plaster cast. This was applied with the knee in full extension and the foot in neutral dorsiflexion. This cast was often left solid until exercises were begun, unless there were circulatory reasons for not doing so. More often, however, preference was given to bivalving the cast, not shifting the foot position, and strapping the two portions of the cast tightly together (Fig. 2). In this way the cast was prepared for its subsequent use as a bivalved unit and, at the same time, permitted observation if it were thought necessary.

EXERCISE REGIMEN

On the average, active plantar flexion and dorsiflexion exercises were begun one to two weeks postoperatively. In a young uncooperative patient with little control, this might well be postponed for a month. This was not the common procedure, however. The time of the first exercises usually varied with the cooperation of the patient. Once the cast was bivalved, the patient spent all of the twenty-four-hour period in the cast, except during his exercise periods. These were usually performed three times a day. In the exercise periods, an increasing range of dorsiflexion and plantar flexion was gradually developed. Every effort was made to develop and to maintain a full range of motion. At six to eight weeks postoperatively standing under supervision, usually with

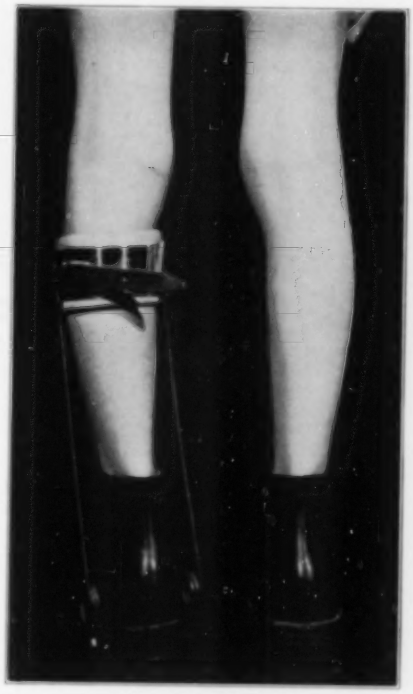

FIG. 3-A

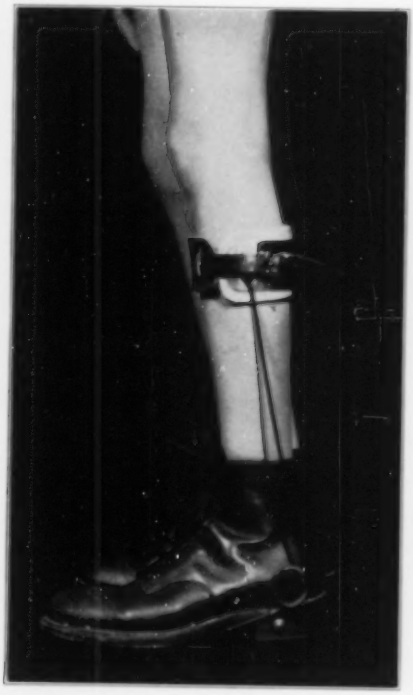

FIG. 3-B

Dorsiflexion spring brace often used preoperatively. It may be used postoperatively where dorsiflexion power is inadequate.

crutches, was begun. After satisfactory balance was established, which might require another few weeks, gait-training with crutches was begun. If the patient had good balance, such as that in a hemiplegic patient, crutches would be used for at least six months until a good gait pattern was established. Many quadriplegic patients required the indefinite use of crutches to assist in their balance. For the average patient, a bivalved cast, with the knee kept in extension and the foot in neutral dorsiflexion, was used at night for at least two years (Fig. 2). In the young patients this might well be for a longer period of time, as long as there was a tendency toward equinus. Some simple support at night might be indicated throughout the growing period. If the patient was cooperative and had good balance standing, he might be taught how to stretch his heel cord against the wall. If he was able to maintain the correction in this way and had developed good power in dorsiflexion, use of the cast might then be omitted. In those few patients who had difficulty postoperatively in carry-

ing out active function of the dorsiflexors, a short dorsiflexion spring brace was used temporarily (Figs. 3-A and 3-B). Obviously, if there was any tendency toward weakness of the gastrocnemius, use of such a brace was deferred.

FRACTIONAL LENGTHENING OF THE GASTROCNEMIUS ORIGIN

In ten patients, the operation of choice for the correction of equinus deformity on nineteen occasions was a fractional lengthening of the gastrocnemius origin which was described by Green in the previous series from this hospital [2]. This involved a lengthening of the tendinous origin of both heads of the gastrocnemius (Figs. 4-A and 4-B). Ordinarily (sixteen operations), the procedure

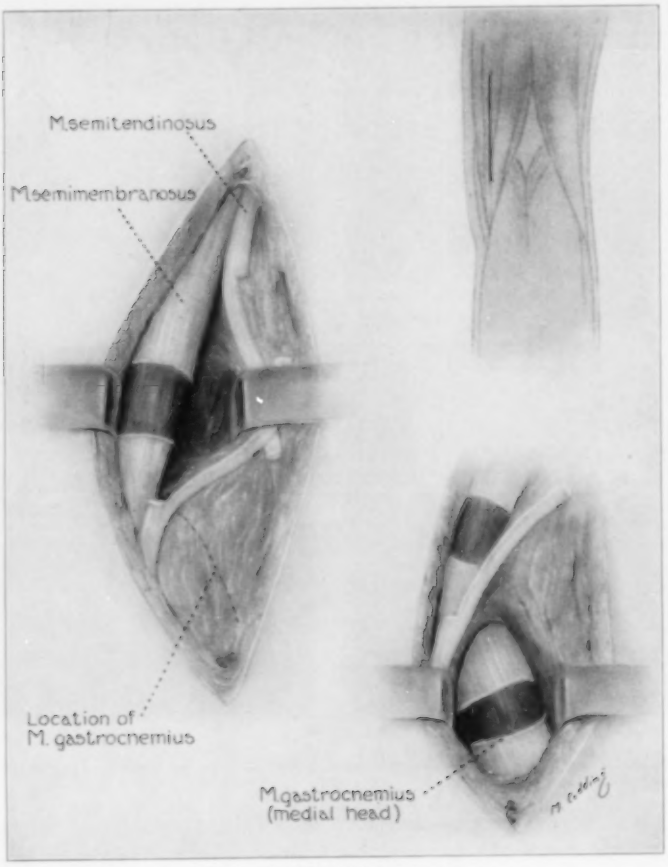

FIG. 4-A

Fractional lengthening of the gastrocnemius is performed as a secondary procedure with hamstring lengthening for knee flexion and equinus deformity.

was done in combination with hamstring lengthening in which this was the primary procedure. The same exposure permitted in an easy way some correction of the equinus deformity. It was not ordinarily used as a primary single procedure. It was most often performed when knee-flexion deformity was marked. In fourteen instances, this procedure was also combined with a Stoeffel neurectomy of the nerve to one head of the gastrocnemius. Three fractional lengthenings were performed without hamstring lengthening but with neurectomies. It is of interest that all of these procedures were performed on quadriplegic patients. Six of the nineteen were followed after an interval by sliding

heel-cord lengthenings because of inadequate correction of the equinus deformity. The postoperative management of these patients was essentially the same as that followed in those who had had heel-cord lengthenings. The period of gait training was usually much longer, however, because these were severely involved quadriplegic patients. Five of these ten patients were not walking before operation.

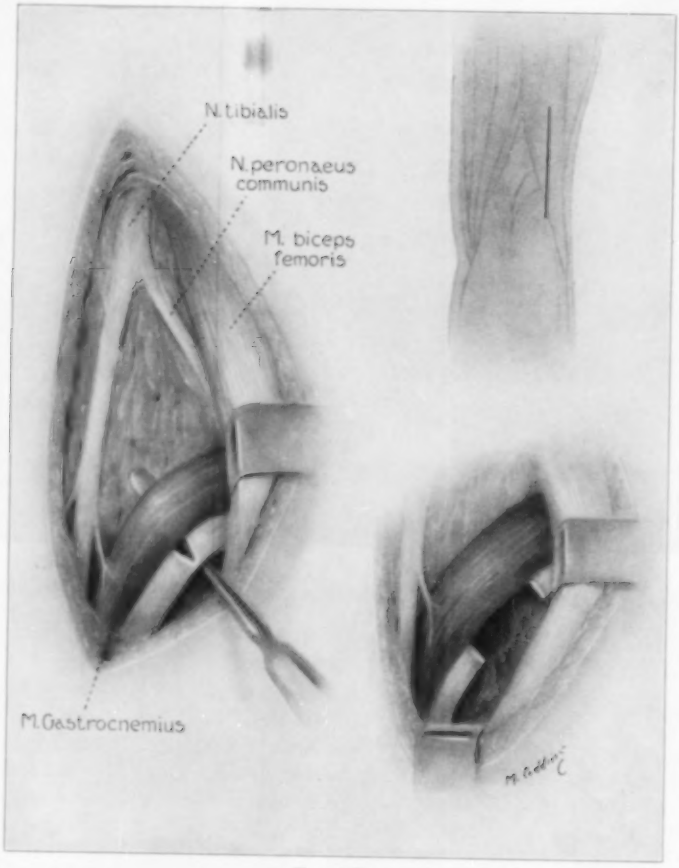

FIG. 4-B

The tendinous portion of medial and lateral heads of gastrocnemius are sectioned. Neurectomy of the nerve supply to one head of the gastrocnemius was performed at the same time in all but five.

NEURECTOMIES

The Stoeffel neurectomy of part of the nerve supply of the gastrocnemius has been infrequently performed recently in this hospital because of previous experiences with this technique in which the incidence of either inadequate correction or overcorrection with calcaneus deformity was high. Neurectomy ordinarily involved the nerve supply of one head of the gastrocnemius. Neurectomy alone was performed three times. After two of these operations heel-cord lengthenings to correct residual equinus deformity were eventually required. On fourteen occasions neurectomy was combined with a fractional lengthening of the gastrocnemius origin. After six of these, heel-cord lengthening was subsequently done.

FIG. 5-A

FIG. 5-B

B. H. Age two. Right hemiplegia. Marked contracture right heel cord. No previous treatment.

TRIPLE ARTHRODESES

In twenty patients a triple arthrodesis was performed on twenty-four occasions. Four patients had triple arthrodesis done bilaterally. Five arthrodeses were performed in the presence of equinus without other deformities. Moderate equinus deformity associated with severe varus, valgus, or cavus deformity was present preoperatively in nineteen others. Seven of these had previous heel-cord lengthening.

In these arthrodeses, the cuts in the bones were patterned so as to correct equinus deformity. One of the twenty-four arthrodeses was subsequently revised because of residual equinovarus deformity. The postoperative care of these patients was essentially the same as that of the patient who had foot arthrodesis for other conditions. Immobilization was carried out for an average of three months. Active exercises were then started. The foot was retained in a bivalved cast part of the time and eventually only at night. Gait-training with crutches was instituted as soon as there was evidence of satisfactory union.

METHOD OF END-RESULT EVALUATION

End-result evaluations in cerebral palsy are difficult for several reasons. The degree of involvement and the amount of handicap are most variable and any grading depends upon the evaluation of many factors. There are many modifying factors such as the patient's motor involvement, his mental development, and his age at the time of surgery and at follow-up examination. The results to be obtained under the best of circumstances are those of relative improvement rather than normal status. There is great variation in the amount of

deformity and disability preoperatively and in the potentiality of muscle function.

The patients were first evaluated on the basis of improvement which weighed their final status in relation to their original condition. Therefore, the patients were classified according to motor status. This classification took into consideration the degree of spasticity, the disturbance in coordination and balance, overflow responses, and control. Those least affected as regards motor impairment were classified in Group One; those most severely affected in Group Five. Such an evaluation of the motor status of the patient preoperatively permitted a more critical assessment of the result based on the potentialities of functional improvement in the given individual. On the basis of improvement of the patient the procedures were graded under five classifications: *no improvement, one* +,

TABLE I

LENGTHENING OF HEEL CORD

(Total Operations 164)

	No. of Cases	Per cent
Excellent	22	13.4
Good	92	56.1
Fair	34	20.8
Poor	14	8.5
Not rated	2	1.2

	Rating of Improvement					
Total	++++	+++	++	+	0	Not Evaluated
164	29	55	57	8	13	2

FIG. 5-C

FIG. 5-D

B. H. Age seven. Persistent equinus deformity noted just before heel-cord lengthening May 29, 1941.

FIG. 5-E

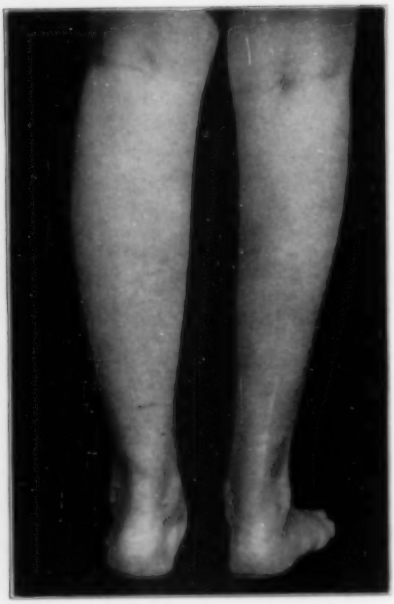

FIG. 5-F

B. H. Age twenty-one. Fourteen years postoperatively. Equinus deformity well corrected.

TABLE II

FRACTIONAL LENGTHENING OF THE GASTROCNEMIUS ORIGIN

Total	Result: Excellent	Good	Fair	Poor	No Follow-up
19	0	8	7	4	0

All but three with hamstring lengthening.
All but five with neurectomy of one head of gastrocnemius.

Total	Rating of Improvement: ++++	+++	++	+	0
19	0	6	6	7	0

two +, *three* +, or *four* +. Results in twenty-nine procedures were rated *four* +; fifty-five, *three* +; fifty-seven, *two* +; eight, *one* +; and thirteen, *no improvement*. In two, the results were not evaluated.

In addition, operative results were also rated *excellent*, *good*, *fair*, or *poor*. This classification was based solely upon the functional performance at the final examination. The results were evaluated on the basis of stance, gait, and active and passive dorsiflexion. Associated foot deformity was also taken into consideration. A heel-toe gait without hyperextension of the knee, the presence of active and passive dorsiflexion of the foot to neutral or above, along with an adequate take-off, were required for a result to be rated *excellent*. When the foot struck the ground in gait as a unit and cleared well, when there was active and passive dorsiflexion to neutral, and when there was good power in the gastrocnemius the result was considered *good*. In patients who tended to plant their foot as a unit as they walked, but in whom the heel struck last and in whom active and passive dorsiflexion did not quite come to neutral, the result was considered *fair*. In those patients who walked toe-heel and hyperextended the

knee or walked on tip-toe, and in addition who lacked a good degree of neutral dorsiflexion, actively and passively, with the knee extended or flexed, the result was considered *poor*. When there was a significant calcaneus deformity after operation, the result was considered *poor*.

FIG. 5-G

B. H. Age twenty-one. Fourteen years postoperatively. Phantom views (double exposure) showing active dorsiflexion to a right angle.

RESULTS

Heel-Cord Lengthenings

In 112 patients, 164 heel-cord lengthenings were performed (Table I). Of these procedures, 162 were evaluated. Two procedures were performed after neurectomy and cannot be evaluated because of inadequate follow-up. Twenty-two lengthenings were rated *excellent;* ninety-two, *good;* thirty-four, *fair;* and fourteen, *poor*. Approximately 50 per cent of the poor results were in patients with Type Four motor status, whereas 65 per cent of the good and excellent results were in the patients with Type One and Type Two motor status. Of the forty-eight procedures rated *fair* or *poor*, thirty (63 per cent) were in quadriplegic patients. Twenty-one of these procedures had been done in patients not walking before surgery. In fifteen of the thirty-four procedures rated *fair*, follow-up was inadequate and the cooperation of the patient and his family was poor. In thirteen of the fourteen procedures rated *poor*, the care in the post-operative period was inadequate.

In the total series, there were eight instances of calcaneus deformity, five of which were persistent. Three instances of this deformity were noted early after operation in two patients. In one patient this was due to overcorrection, and subsequent treatment reversed this tendency. In the other patient the deformity was due to a related flexion deformity of both knees. In this patient the lengthened tendons were stretched by excess strain resulting from continued walking with a flexion deformity of the knees. After the flexion deformity of the knees was corrected by hamstring lengthening, the feet in this patient were restored to satisfactory function and the calcaneus deformity was automatically corrected. In the remaining three patients no reason for calcaneus deformity could be found other than possible overcorrection.

In evaluating the result after heel-cord lengthening, attention was given to the original strength of the muscles of dorsiflexion in relation to the end result.

It was possible to evaluate fifty-three procedures on this basis. In nine instances, these muscles were rated *good* to *normal* preoperatively, and the results were rated *excellent* in two, *good* in six, and *poor* in one. In eighteen, these muscles were rated *fair* or *fair plus* preoperatively, and the results were rated *excellent* in three, *good* in eight, *fair* in six, and *poor* in one. In eleven, the muscles were rated *poor* or *poor plus*, and the results were *excellent* in two, *good* in six, *fair* in two, and *poor* in one. In fifteen, they were *trace*, and the results were rated *excellent* in one, *good* in nine, *fair* in four, and *poor* in one.

TABLE III

NEURECTOMY—GASTROCNEMIUS (STOFFEL)

Operation on	Total	Result			
		Excellent	Good	Fair	Poor
Nerve alone	3	1	0	0	2
Nerve with fractional lengthening of gastrocnemius origin	14	0	4	6	4

Fractional Lengthening of the Gastrocnemius Origin

The method of end-result evaluation after fractional lengthening of the gastrocnemius origin was the same as that for heel-cord lengthening. In ten patients, nineteen fractional lengthenings of the gastrocnemius origin were evaluated (Table II). All of these procedures were performed in patients whose motor status was rated *four* or, in other words, who showed a marked disturbance in motor function. Five of the ten patients were not walking before surgery.

In no patient did the procedure result in improvement rated *four* +; in six the result was rated *three* +; in six others the result was rated *two* +; and in seven the improvement was rated *one* +. At the time of follow-up examination, three patients who had been unable to walk preoperatively were able to move about using crutches after the procedures and additional surgery. Two were still unable to walk more than a few steps with great assistance. The remaining five were able to walk about quite well with or without crutches.

On the basis of the functional status of the part at the final examination, results in eight were *good;* in seven, *fair;* and in four, *poor.* In six the procedure was subsequently followed by heel-cord lengthening; the results have been evaluated previously. Triple arthrodesis was performed in association with fractional lengthening and hamstring lengthening on two occasions. Results from both were rated *good* and are included in the foregoing statistics. Triple arthrodesis was later performed in one patient for correction of valgus deformity and some residual equinus deformity.

Neurectomy

In three instances (two patients) neurectomy to one head of the gastrocnemius (Table III) was done. In one the result was classified *excellent* on the basis of the functional status of the part at the follow-up examination. This patient, however, was considered to show *one* + improvement inasmuch as preoperatively he had had a mild degree of deformity. After the other two procedures in which neurectomy alone was performed, the second patient subsequently required heel-cord lengthening because of inadequate correction of equinus deformity.

Of the fourteen neurectomies which were associated with fractional lengthening of the gastrocnemius origin (Table III), results in four were rated *good;* in six, *fair;* and in four, *poor.* Following six of the fourteen procedures in which neurectomy was combined with a fractional lengthening of the gastrocnemius origin, heel-cord lengthening, as recorded previously, was eventually done.

TABLE IV

ARTHRODESIS OF THE FOOT

Indications	Total	Result: Excellent	Good	Fair	Poor
Equinus deformity	5	0	2*	3	0
Equinus and associated other deformity	19	1	8	4	6

Rating of Improvement: Total	++++	+++	++	+	0
24	2	9	7	4	2

*Associated fractional lengthening of gastrocnemius and hamstring lengthening.

Triple Arthrodesis

Arthrodesis of the foot was evaluated on the basis of correction of equinus deformity (Table IV), as well as on the basis of the effectiveness of the arthrodesis in producing a foot of good contour, good height, and stable position of weight-bearing. On the basis of improvement of the patient, two procedures were graded as resulting in improvement rated *four* +; nine rated *three* +; seven rated *two* +; and four rated *one* +. Two procedures resulted in no improvement.

Of the twenty-four arthrodeses, five were done for correction of a moderate degree of equinus without other associated deformity; results in two were rated *good* and in three *fair.* Two of the good results were associated with fractional lengthening of the gastrocnemius origin which probably qualified the results in these instances. In nineteen feet, triple arthrodeses were performed in the presence of equinus deformity with moderate valgus, varus, or cavus deformity. In these, the result in one was rated *excellent;* results in eight were rated *good,* in four, *fair,* and in six, *poor.* The excellent result occurred in a patient who had a moderate cavus deformity. Seven of the nineteen feet in which an arthrodesis was performed for equinus deformity with associated valgus, varus, or cavus deformity had had previous heel-cord lengthening. One of these patients had had heel-cord lengthening done before the present series. In two of the eight feet in which good results were obtained, previous heel-cord lengthening had been done, and in one with a fair result heel-cord lengthening had been done. Five of the six feet with poor results had little observation or care after operation.

In none of these procedures did non-union of the arthrodesis result, and in only one was revision necessary because of residual varus deformity and adduction of the fore part of the foot.

DISCUSSION

As has been pointed out by Baker, the conservative non-operative treatment of patients with cerebral palsy has been overemphasized in recent years, and in turn, this emphasis has overshadowed the benefits derived from many surgical procedures. Throughout the literature, there are statements which give the un-

FIG. 6-A

FIG. 6-B

P. B. Age seven. Right hemiplegia. Equinovarus right foot with marked adduction prior to heel-cord lengthening.

FIG. 6-C

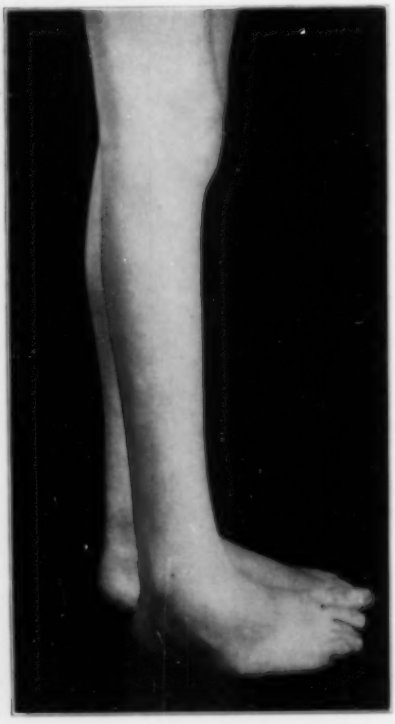

FIG. 6-D

P. B. Age nine. Equinus deformity corrected. Varus and adduction persist after heel-cord lengthening. Preoperative triple arthrodesis.

FIG. 6-E

FIG. 6-F

P. B. Age nineteen. Eleven years after heel-cord lengthening. Nine years after triple arthrodesis.

FIG. 6-G

P. B. Preoperative x-rays, 1946.

initiated the impression that orthopaedic surgery is of little value in cerebral palsy. It is stated time and again that there is no point in operating on patients with cerebral palsy because all, or nearly all, of the deformities recur anyway. Some believe that surgery should be postponed until the end of the growing period when an arthrodesis of the foot should be performed to correct equinus deformity. It has been stated that most patients with equinus deformity can safely and satisfactorily be treated with braces at night.

Contrary to this point of view, it has been our experience over the years that orthopaedic surgical procedures have a major role in the management of patients with cerebral palsy [2]. Surgery adequately performed on properly selected patients and followed by careful postoperative management yields good results (Figs. 5-A through 5-G). Our experience with the surgical correction of equinus deformity substantiates this. In the fifteen-year period from 1940 through 1954, 255 operative procedures have been performed on 153 patients for correction of equinus deformity. Of these, 224 procedures in 136 patients have been evaluated. These include 164 heel-cord lengthenings, nineteen fractional lengthenings of the gastrocnemius, seventeen Stoeffel neurectomies, and twenty-four triple arthrodeses. The results have been satisfactory. Only thirty of the 224 procedures gave results rated *poor*. Of 164 heel-cord lengthenings, only six secondary lengthenings were performed. Five of these, on careful review

FIG. 6-H FIG. 6-I

P. B. Postoperative x-rays, 1955.

of the patient's records, were not done for recurrence of deformity. Seven heel-cord lengthenings were subsequently followed by triple arthrodeses (Figs. 6-A through 6-I). These were usually for correction of some deformity of the foot other than primarily for equinus deformity, but all of the patients had a mild degree of residual equinus deformity at the time of arthrodesis. In those patients who underwent a triple arthrodesis in the presence of severe equinus deformity without valgus, varus, or cavus deformity, the foot could be well aligned after the arthrodesis but dorsiflexion was still limited.

Of the 164 heel-cord lengthenings, nine of the fourteen procedures in which results were rated *poor* were followed by a recurrence of the equinus deformity (5.5 per cent). These were usually associated with poor and inadequate follow-up, poor cooperation on the part of the patient and family, a motor status

in the lower classification, and severe mental retardation. In five feet with poor results, there was residual calcaneus deformity.

Contrary to the statements frequently made that surgery should not be performed on patients with cerebral palsy until growth is complete, the age of the patients reported in this paper was from two years and ten months to fourteen years. Not only were there no untoward effects from surgery in the early ages, but the procedures permitted early correction of deformities and rapid improvement in functional capacities.

It is frequently stated that surgery has the most to offer in the patient with the spastic type of cerebral palsy. All patients in this series had spastic cerebral palsy and two had some athetosis in addition. As reported in our previous series [2], the worst results are obtained in those with athetosis although some degree of athetosis should not of itself be a contra-indication to a procedure. It is well, then, to evaluate a patient thoroughly in order to determine what type of cerebral palsy he has before considering a surgical procedure.

The presence or absence of sitting, standing, or walking balance is important in deciding whether or not surgery of the lower extremity is indicated. If a patient is so severely involved that he makes no attempt to turn over in bed, sit, stand, or walk, surgical procedures are not indicated. If, on the other hand, he demonstrates good sitting and standing balance but has difficulty in walking because of a deformity that has not responded to conservative treatment, such a deformity should be corrected. Likewise, if the patient is walking but has an equinus deformity which has not responded to the usual conservative measures, the deformity can be corrected with dispatch to improve function and to simplify the problem of training. It is not essential that the patient be walking at the time of surgery, but he should have satisfactory balance and control and the potentiality of walking, if surgery is to be performed on the foot. Sixty-nine procedures were performed in thirty-one patients who were not walking or who were just able to take a few steps with support. Surgery enabled all except four of these to begin walking, usually with crutches.

It is frequently stated that surgical procedures should be performed on a patient who is mentally able to cooperate and to take advantage of the improved position of his feet and the function in his extremities. While a good mental state is very helpful in the rehabilitation of these patients and in training them in the proper use of their extremities, it is not essential. Sixty-two of the patients in this series were mentally retarded. Eighteen of these had intelligence quotients of fifty or less. In eleven of these, there were good results; in three, fair results; and in four, poor results. Even though a patient is quite retarded mentally, it is worth while to perform surgical procedures that will enable him to walk. Certainly a patient is easier to manage if he can walk, even if with support.

Much importance has been attached to the presence of muscle weakness of the foot in relation to the treatment of equinus deformity. Certainly it is well to have some idea of the power of the foot muscles before surgery, but whether these muscles appear weak or poor should not make one avoid surgery. It would appear that the muscle weakness frequently described is ordinarily due to a failure to observe the details of examination. Occasionally the tibialis anterior and other dorsiflexors of the foot are unable to actively dorsiflex the foot because of the overwhelming spasticity of the gastrocnemius. Even though they may demonstrate some action, they are unable to work against such a deforming force. Not infrequently muscles that do not contract on ordinary tests may be brought into action by various maneuvers of position and stimulation. For example, by flexing the knee and relaxing the gastrocnemius and by varying other positions, an apparently powerless tibialis anterior may be made to function. Apparent weakness of the dorsiflexors does not compromise the end

result as attested by the results in our series. We have seen good and excellent results in patients who appeared to have weak dorsiflexors; we have also seen poor results in patients who appear to have good dorsiflexors.

Our choice of technique for the correction of equinus deformity is the sliding lengthening in which the heel cord is actually lengthened in continuity. The lengthening of the muscle allows the foot to be flat on the floor in stance without provoking a stretch reflex. The lengthening, by diminishing the amplitude of contraction, weakens the strength of the gastrocnemius-soleus axis relative to power in dorsiflexion, so that a balanced agonist-antagonist relationship can be established. The lengthening must allow the foot to go comfortably to a right angle and yet be snug at this point. The length must not be excessive or a calcaneus deformity may result. Careful continued postoperative care is essential in order to obtain a good result. As in any soft-tissue procedure in cerebral palsy, maintenance of the corrected position for a long time after operation with the use of removable casts, initially during both the day and night and subsequently at night, is essential. If, after operation, it appears for an interval that the dorsiflexors are very weak, one should apply an adequate brace to assist dorsiflexion. A long period of gait training, with an effort at trying to establish a normal gait pattern, is invaluable in the management of these patients. It is also exceedingly important to develop active function of the dorsiflexors of the foot and also to maintain active plantar flexion. Crutches may be very helpful in this regard. In the postoperative period one of the advantages is that when the patient is adequately immobilized and prevented from walking for six weeks, there appears to be a relaxation in over-all spasticity and the patient is much more easily controlled and trained.

When a hamstring lengthening is being performed in the presence of flexion deformity of the knee, a combination of this procedure with a fractional lengthening of the gastrocnemius origin may give satisfactory results, particularly with a mild degree of equinus deformity. It should not be considered as a primary procedure for the correction of equinus deformity, however. Some patients may require secondary heel-cord lengthening after this procedure.

If there is instability at the subtalar joint and associated deformity of the foot, such as a disturbing valgus or varus deformity, an arthrodesis should be done at the appropriate time. This will help to simplify motor control. A combination of heel-cord lengthening and subtalar extra-articular arthrodesis [3,4] after the age of five will correct a valgus deformity quite adequately, give a very stable foot, and may avoid the necessity for doing a triple arthrodesis at a later age. Severe equinus deformity should not be corrected by triple arthrodesis alone because too much bone must be removed, resulting in a foot with markedly diminished height.

SUMMARY

Orthopaedic procedures for the correction of equinus deformity are effective measures in the treatment of spastic cerebral palsy. The best operative procedure for the correction of fixed equinus deformity in our series was a sliding lengthening of the heel cord. Adequate postoperative management of these patients is essential in order to obtain a good result. Long-term support out of equinus position at night during the growing period, and an exercise regimen to develop balanced muscle function between agonist and antagonist are essential to an effective result.

Whereas stabilization of the foot is an effective measure in correcting varus or valgus deformity and simplifying the control of the foot in older individuals, it should not be used as a procedure to correct severe equinus deformity.

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(*Continued from page 1270*)

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Brucellosis Myelopathy

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Cases of paraplegia with or without sphincter disturbance or sensory impairment, occurring as a complication of brucellosis, have been reported mainly in French, Spanish, and Italian literature. Brucellosis paraplegia is considered one of the group of diseases called neurobrucellosis, a distinct pathological entity [7,13,16,17,20]. Emphasis has been placed on the occurrence of brucellosis meningomyelitis, in which Brucella acts either through the production of meningovascular lesions or through compression of the cord by local arachnoiditis. The power of Brucella to localize in the meninges cannot be doubted [10,19]. The occurrence of meningovascular lesions or of localized arachnoiditis from Brucella is a logical deduction from the occurrence of brucellosis meningitis. Evidence has been adduced to prove their existence. Brucella can affect the spinal cord in other ways also. It is the purpose of this paper to show that brucellosis can produce paraplegia as a complication of spondylitis, possibly by cord compression. In such cases, the cause of the compression is either external to the meninges or, if the meninges are affected, the meningeal lesion is produced by extension from bone. No diagnosis of brucellosis meningomyelitis should be made unless brucellosis myelopathy from compression has been carefully excluded. Compression myelopathy can derive great benefit from early orthopaedic treatment. Patients suffering from the condition may fail to receive important help because the primary cause of the paraplegia is not localized in the spine.

Brucellosis spondylitis simulates tuberculous spondylitis so much that it took a long time to differentiate between the two [11]. Furthermore brucellosis spondylitis, with or without compression on the cord, can result from the insidious type of brucellosis in which fever may be low or even absent from the start, and other manifestations of the disease may be mild throughout the whole course of the infection. Brucellosis as a cause of spondylitis may go unsuspected if the patient calls at an orthopaedic unit because of pain rather than at a medical ward because of fever. Compression myelopathy may be attributed to tuberculous spondylitis if the surgeon is not aware of the manifestations of spinal brucellosis.

From 1947 to 1954 a total of 6,300 cases of brucellosis were reported to the health authorities in Malta; 1,942 patients were hospitalized, 699 patients attended the orthopaedic unit for brucellosis of bone or joint, and 130 patients had brucellosis spondylitis. Of these 130 patients, ten manifested signs and symptoms of compression myelopathy. The blood-serum agglutination test in four of these patients was carried out only by the slide method; in the other six patients, a titer of at least 1:160 agglutinins of *Brucella melitensis* was found. In two cases the titer was 1:640. Blood culture was positive in one case, and in another case, blood culture was negative on two occasions, yet *Brucella melitensis* was cultured from pus aspirated from a cold abscess. In brucellosis myelopathy, Brucella are rarely found in the blood since the myelopathy develops, as a rule, late in the course of disease.

CASE REPORTS

CASE 1. On June 12, 1951, P.C., a stone lifter, forty-five years old, complained of pain in the upper lumbar region radiating to the right thigh. On examination on June 16, there was spasm of the lumbar muscles of the spine; roentgenograms showed only osteo-arthritic lipping of

the lumbar vertebrae. His temperature was 100 degrees Fahrenheit. The spleen, liver, and lymph nodes were not enlarged. Blood-serum agglutination yielded *Brucella melitensis* by slide reaction. Pain improved rapidly with bed-rest and the patient was discharged at his request. When he called again at the out-patient clinic on July 19 and August 8, he complained of pain near the left iliac crest, but movements of the spine were free and painless. On January 12, 1952, he was readmitted with the complaint that he had lately had a temperature of up to 103 degrees Fahrenheit. He had never been quite free of pain. Examination showed a straight, rigid spine due to muscle spasm and loss of lumbar lordosis. Roentgenograms showed erosion of the contiguous borders of the twelfth thoracic and first lumbar vertebrae with cloudiness and narrowing of the disc space. The patient was afebrile, but looked ill. The spleen, liver, and lymph nodes were not enlarged. There were no neurological findings, and a roentgenogram of the chest

FIG. 1-A

was clear. The result of the Mantoux intracutaneous test for tuberculosis was 1:1000, only slightly positive. Blood studies revealed 8,800 leukocytes per milliliter. The differential blood cell count revealed polymorphonuclear neutrophils, 68 per cent; lymphocytes, 28 per cent; and monocytes, 4 per cent. A sample of venous blood, collected from the arm on February 2, did not yield a culture, but on January 29, blood-serum agglutination yielded *Brucella melitensis* at a titer of 1:640.

Roentgenographic examination on February 2 showed an additional tilt of the lumbar spine to the left. The patient improved rapidly on a Bradford frame; in a week he complained only of mild lumbar pain which radiated to both thighs. Aureomycin was given orally in doses of three grams a day for twenty-one days with vitamin B-complex tablets. On March 3, he was again discharged at his request.

On April 15, the patient was readmitted under emergency conditions. A few days after leaving the hospital, severe lumbar pain developed followed by weakness of the right lower extremity and loss of sphincter control. On examination the lumbosacral spine was rigid, and there was acute tenderness over an area to the left of the lumbar spine. The patient looked ill. He had neck rigidity and loss of motor power of both lower extremities. The muscles were flaccid; reflexes were absent; and tests for plantar reflex showed a doubtful extensor response. The response to sensory stimulation was doubtful, but it was felt that there was hyperaesthesia at the level of the first, second, and third lumbar vertebrae. Below the third lumbar vertebra, sensation was diminished more on the right than on the left. No neurological changes were found above the level of the lumbar spine. The blood leukocytes were now 12,800 per milliliter; there were 58 per cent polymorphonuclear neutrophils, 38 per cent lymphocytes, and 4 per cent monocytes. Roentgenograms of the twelfth thoracic and the first lumbar vertebrae showed that the erosion of the contiguous borders had increased, particularly on the left side, and that the intervertebral-disc space had narrowed further (Figs. 1-A and 1-B). The tilt to the left had been partially corrected. Lumbar puncture performed on April 21 showed an initial cerebrospinal-fluid pressure of 170 millimeters which rose rapidly to 350 millimeters on compression of the jugular vein, and fell to the initial level within ten seconds of decompression. The spinal fluid was turbid. Spinal-fluid studies showed 180 milligrams of protein per 100 milliliters; 740 milligrams of chlorides per 100 milliliters; and fifty-five milligrams of sugar per

100 milliliters of fluid. There were thirty-five leukocytes per milliliter of fluid, composed of five polymorphonuclear neutrophils, twenty-seven lymphocytes, and three endothelial cells. The fluid did not yield a culture, and venous blood was sterile again, but *Brucella melitensis* was isolated from pus which on that day had been evacuated from a cold abscess that was forming deeply on the left side of the lumbar spine. About twenty milliliters of pus had been aspirated consisting of debris, occasional erythrocytes, and disintegrating leukocytes. Another blood-serum agglutination was positive with a titer of 1:160. The patient was again treated on a Bradford frame and again received three grams of aureomycin orally each day for twenty-three days. His general condition improved rapidly; he felt better, and remained afebrile. The abscess did not enlarge, and movement of the lower limbs was returning on May 3. On May 19 rapid improvement of motor power and of superficial sensation was recorded. Roentgenograms

FIG. 1-B

FIG. 1-C

Figs. 1-A and 1-B: Case 1. Roentgenograms of the twelfth thoracic and first lumbar vertebrae showed that erosion of contiguous borders had increased.
Fig. 1-C: Roentgenograms made in October 1953 showed that the spondylitis was inactive.

did not show any change, but on June 14 motor power was recorded as very good, and on July 15 the patient was fitted with a plaster jacket and sent home. When seen as an out-patient on August 29, he had recovered from his neurological symptoms. On September 4 roentgenograms showed some sclerosis of the eroded vertebral surface and osteo-arthritic bridging on the left side between the twelfth thoracic and first lumbar vertebrae. The intervertebral-disc space remained very narrow but was clear.

The patient was depressed and cried easily; this depression lasted about a year. Motor power had returned and, at physical examination, sensation was normal. Roentgenograms of the spine in October 1953 revealed that the spondylitis was inactive (Fig. 1-C). The erythrocyte sedimentation rate was within normal limits.

CASE 2. S. G., a baker, fifty-two years old, had fever early in December 1952. On December 18, he had severe pain associated with the pelvic-nerve distribution at the umbilical level. This was followed by numbness of the lower limbs extending to the umbilicus and by heaviness of both lower limbs. In two days, complete paralysis of the lower limbs, retention of urine, and constipation developed. Catheterization was necessary for two days. Constipation lasted ten days. Motor power of the lower limbs returned slowly. In February 1953, he could stand but could not walk.

He returned to the hospital on April 6. He had a spastic gait and increased reflexes in the lower limbs with bilateral patellar and ankle clonus. All sensation was diminished below the umbilicus. Patient was not in pain; however, movements of the spine, especially flexion were

limited. No tenderness was elicited over or near the spine. Roentgenogram (Fig. 2-A) showed a narrowing of the intervertebral-disc space between the seventh and eighth thoracic vertebrae with small areas of bone destruction at the postero-inferior part of the seventh thoracic vertebra. The patient's general condition was good. He was afebrile, and the spleen, liver, and lymph nodes were not enlarged. Roentgenograms of the chest were normal. Mantoux intracutaneous test for tuberculosis was 1:1000, only mildly positive. Blood-serum agglutination revealed *Brucella melitensis* at a titer of 1:640. Blood culture yielded no growth. Erythrocyte sedimentation rate (Westergren) was eight millimeters in the first hour. Spinal manometry revealed a normal initial pressure of the cerebrospinal fluid with a rapid rise and fall on compression and decompression of the jugular veins. The spinal fluid was grossly contaminated with blood and was discarded.

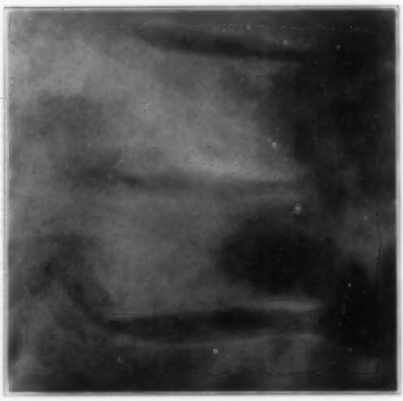

FIG. 2-A

FIG. 2-B

Fig. 2-A: Case 2. Roentgenogram made on April 7, 1953.
Fig. 2-B: Roentgenograms made on July 17, 1954, showed osteo-arthritic changes.

On April 17 the patient was put on a Bradford frame; traction to the spine was attained by halter traction to the head and strapping extension to the lower limbs. By the end of May motor power was strong in both lower limbs, and clonus was absent. Tests for both plantar reflexes showed flexor response; sensation was practically normal. Traction was removed on June 20.

Roentgenograms (Fig. 2-B) showed that the body of the ninth thoracic vertebra was healing with patchy sclerosis. A plaster-of-Paris jacket was applied and worn from June 20, 1953, to January 20, 1954. On September 11, 1953, roentgenograms of the spine still showed the diminished intervertebral-disc space between the seventh and eighth thoracic vertebrae with calcification of the outer border of the disc. There were osteo-arthritic changes from the fifth to the twelfth thoracic vertebrae. Further examination in January 1954 and 1955 showed that the patient was clinically normal. He returned to work in March 1954.

CASE 3. A sixty-year-old goatherd complained of intermittent pain in the mid-portion of the thoracic spine in February 1954. It was necessary for her to remain in bed from May until she was relieved of pain in July. In late August, paraesthesia developed in both lower limbs. On examination on September 3, motor power of the lower limbs was not seriously impaired. The knee reflexes were normal; ankle reflexes were diminished and tests for plantar reflexes showed flexor response. There was impairment of sensation to touch and pinprick below the knees. Sensation to temperature and vibration was absent in the lower limbs. Roentgenograms of the spine showed slight erosion of the upper margin of the seventh thoracic vertebra and marked erosion of the lower margin of the sixth thoracic vertebra. The body of the sixth thoracic vertebra was slightly collapsed and the intervertebral-disc space between the sixth and seventh thoracic vertebrae was narrow. An abscess sheath extended downward from the level of the fifth thoracic vertebra. Osteo-arthritic lipping and osteophytes were present. The patient's general condition was fair. There was no enlargement of spleen, liver, or lymph nodes. She was afebrile, and roentgenograms of the chest were normal. Mantoux intracutaneous test for tuberculosis was positive, 1:10,000. The patient was put in a plaster bed and treatment with streptomycin and para-aminosalicylic acid was started; however, the patient's condition became worse. Incontinence of urine and faeces developed and she lost motor power of her lower limbs. Below the knees her power was zero; at the glutaei and hamstring muscles it was about 2 to 2.5. The knee reflexes disappeared, and the tests for plantar reflexes showed an extensor response. Sensation to pinprick disappeared to the level of the eleventh thoracic vertebra, but

light touch was still appreciated although impaired. Sores developed on the buttocks. Blood studies revealed 16,350 leukocytes per milliliter of blood, and the erythrocyte sedimentation rate (Westergren) was fifty-six millimeters in the first hour. Brucellosis was now suspected. Agglutination titer was 1:320. Blood culture yielded no growth. Attempts to aspirate pus for culture from the deep paravertebral abscess were unsuccessful.

The patient improved after 1.5 grams of aureomycin were given daily for twelve days. In the middle of October, the patient was aware of deep pressure in all locations; pinprick was felt down to the first lumbar vertebra. Late in November she was able to move her toes. Roentgenographic examination, on January 12, 1955, revealed the onset of bone sclerosis. In May 1955 motor power had returned to all muscle groups. Erythrocyte sedimentation rate (Wes-

FIG. 3-A

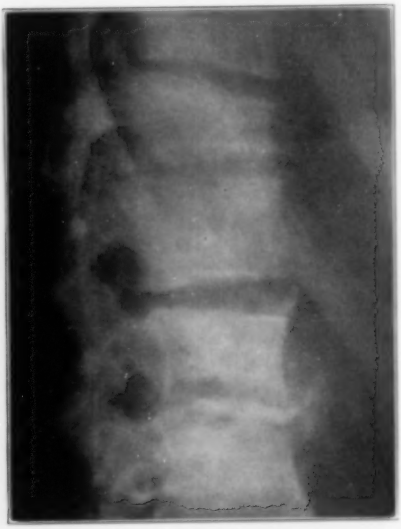

FIG. 3-B

Case 4. Roentgenograms made on September 13, 1949, revealed advanced spondylitis of the twelfth thoracic and the first, second, and third lumbar vertebrae.

tergren) was four millimeters in the first hour. Roentgenograms at this time showed that the paravertebral abscess was shrinking. In the middle of August the patient was able to walk with support. In the middle of September her gait was steady, and she was discharged. Roentgenograms of the spine showed that the vertebral erosions had been replaced by dense bone. The intervertebral-disc space was narrow but surrounded by neatly cut margins; the paravertebral abscess was still shrinking. In November, neurological examination was normal, and she returned to active employment.

CASE 4. S. T., a farmer, thirty-seven years old, had undulant fever for several months during 1948 and 1949. In May 1949 he complained of weakness of the lower limbs. In August, he was bedridden with paralysis of the lower limbs. On admittance to the hospital on September 7, there was spasticity of the lower limbs; knee and ankle reflexes were increased; bilateral ankle clonus was elicited; and tests for plantar reflexes showed an extensor response. Vibration sense and deep-position sense were lost bilaterally. Superficial sensation to pinprick, touch, and temperature was generally absent in the legs and feet, but was still present on the soles of the feet and backs of the legs. There was no loss of sensation over the gluteal regions and buttocks. Roentgenograms made on September 13 (Figs. 3-A and 3-B) showed advanced spondylitis of the twelfth thoracic and first, second, and third lumbar vertebrae. The twelfth thoracic vertebra was wedged. Marked erosion was visible on the left lower border of the first lumbar vertebra. Both contiguous borders of the second and third lumbar vertebrae were eroded; the intervertebral-disc space was narrowed; and small abscesses were forming at the sides. The patient's general condition was fair. The spleen, liver, and lymph nodes were not enlarged.

The patient was operated upon on September 16. The laminae were removed from the twelfth thoracic to the second lumbar vertebra. At surgery, it was noted that the tissues were caseous in consistency, bleeding was considerable, the structures were adherent, and pus exuded from various places. The spinal cord had a twist in the region of the twelfth thoracic vertebra and an extradural abscess surrounded the anterior portion of the spinal cord in this

region. Culture from the pus was negative. Animal inoculation did not show the presence of *Mycobacterium tuberculosis*. Agglutination reaction carried out on the purulent fluid was positive to *Brucella melitensis* at a titer of 1:160. The patient recovered satisfactorily from his operation and his neurological symptoms improved. On February 8, 1950, active movement of the legs was somewhat restricted; however, this was partly due to stiffness of the joints. Eversion of the feet was impossible. There still was bilateral ankle clonus; patellar clonus was elicited on the left only. Sensation to vibration, position, and temperature returned to the lower limbs. Reaction to pain was absent only over a small area of the right shin from approximately three inches to approximately five inches below the knee. Sensation to touch was absent only on the soles of both feet. The sphincter functions were normal. The patient improved further with physical therapy and insisted upon going home. It was reported that he was able to walk fairly well in June and even better in October. He failed to report for further examination; however, his family doctor reported a full recovery.

FIG. 4

Case 5: Roentgenograms made on February 26, 1947, showed extensive erosion of the fourth and fifth cervical vertebrae and collapse of the fifth cervical vertebra.

CASE 5. S. M., a truck driver, thirty-six years old, had fever from January to July 1946. Diagnosis was made when blood-serum agglutination yielded *Brucella melitensis* by slide reaction. During July, the patient complained that he had a lump in the throat for about a week and swallowing was disturbed. In November, fever recurred with pain in the neck and the upper limbs, and with numbness and weakness of the right upper limb and weakness of the right lower limb. Early in January the left upper limb became weak. On admittance to the hospital on January 11, 1947, the patient was in so much pain that he required morphine. The head was fixed in slight flexion, and prominence of the spinous process of fourth cervical vertebra was noted. The patient complained of pain over this region of the neck when his head was tapped. The cranial nerves were normal. The upper limbs were paralyzed, the right more than the left. The right lower limb was slightly spastic with patellar and ankle clonus. The test for plantar reflex gave an extensor response on the right, and a doubtful response on the left. The abdominal reflexes were absent. Heel-to-knee tests were faulty. Superficial sensation to touch and pain was absent over a small area at the radial side of the dorsal aspect of the right hand; pinprick was felt only as a touch on the dorsum of the left foot.

A roentgenogram of the spine (Fig. 4) showed extensive erosion of the fourth and fifth cervical vertebrae; collapse of the fifth cervical vertebra caused forward angulation of the spine at that level. The intervertebral-disc space between the fourth and fifth cervical vertebrae appeared practically obliterated by erosion and cloudiness. The patient was afebrile but the spleen was palpable. Blood-serum agglutination was positive yielding *Brucella melitensis* at a titer of 1:160. Mantoux intracutaneous test was negative. Lumbar puncture showed an

initial pressure of 180 millimeters, rising to 360 millimeters in thirty seconds on compression and falling to 200 millimeters, thirty seconds later, on release. The spinal fluid was slightly turbid with twenty-two milligrams of protein per milliliter, a weakly positive globulin test, and three lymphocytes per milliliter. The patient improved rapidly with halter traction. On February 7, heel-to-knee tests were normal; on February 16, power had returned in most muscles. Head traction was eased on March 1, and on March 22 the patient was discharged in a plaster Minerva jacket. He had recovered completely from his neurological symptoms except for occasional pain and tingling sensations in his right arm and forearm. Roentgenograms made in August 1954 showed that the patient had recovered from spondylitis. Fusion of the fourth and fifth cervical vertebrae and marked osteo-arthritic changes of the upper cervical vertebrae were also noted.

Case 6. A thirty-seven-year-old man had undulant fever in October 1950, and *Brucella melitensis* was cultivated from blood collected on October 7. He received three grams of aureomycin daily for six days starting on October 22. He was afebrile when on November 3 he complained of lumbar pain radiating to the abdomen. This pain was aggravated by movement and the patient was compelled to lie on his right side. On examination, on November 13, there was tenderness along the lumbar spine and sacrospinalis muscle with restricted movement of the lumbar spine. Roentgenograms showed no abnormalities of the spine. The patient's general condition was fair, with a temperature of 101 degrees Fahrenheit. The spleen was palpable, but there was no enlargement of the liver or lymph nodes. Central nervous system and other systems appeared normal. A roentgenogram of the chest was normal. Mantoux intracutaneous test for tuberculosis was positive, 1:10,000. Blood-serum agglutination yielded *Brucella melitensis* at a titer of 1:320. No Brucella was isolated from blood collected on November 21. Lumbar pain and spasm were still severe when, on December 12, weight traction was applied to both lower limbs. Three days later paraplegia developed. It was not accompanied by sensory changes or sphincter disturbance. Lumbar puncture between the third and fourth lumbar vertebrae was performed on December 15 and about one milliliter of turbid xanthochromic fluid, which clotted rapidly, was obtained. It contained about 1000 erythrocytes and 85 leukocytes (composed mainly of lymphocytes) per milliliter. *Brucella melitensis* was cultured from this fluid. Manometry showed an initial pressure of 120 millimeters with a slow rise to 250 millimeters on compression and a slow return to the initial level on decompression. Three grams of aureomycin a day were again given starting on December 26. A myelogram on December 29 showed a block at the level of the third lumbar vertebra. Laminectomy performed on January 3 revealed a peridural abscess at the level of the third and fourth lumbar vertebrae, and the ligamentum flavum between these vertebrae was thickened. No bacteria were isolated by culture, from swabs, or from fluid samples collected during the operation. The patient improved rapidly, and was able to move his toes the following day. Two days after surgery he was able to contract the hamstring tendons and quadriceps femoris on both sides. The patient was removed from the Bradford frame at the end of March. On May 10 he was allowed out of bed. He was still spastic, but by the end of May he was able to attend the out-patient clinic and had no complaints. Administration of aureomycin had been prolonged until the end of January. A blood sample collected on January 30 was negative to Brucella when cultured; however, in March, a small cold abscess developed on the left side of the upper part of the lumbar spine. Blood stained pus was aspirated from it. A culture of *Brucella melitensis* was obtained and the purulent fluid agglutinated *Brucella melitensis* at a titer of 1:640.

COMMENT

Autopsies and experimental observations on the anatomical changes in brucellosis point to the tissues of the reticulo-endothelial system as the most common sites in which Brucella localize. Brucella were isolated from bone marrow as early as 1908 [6], but the importance of bone marrow in this respect was not generally appreciated until Meyer suggested that bacteraemia might be maintained by focal lesions in the bone marrow. In fact Brucella are cultured easily from bone-marrow aspirates. In a series of forty-four cases of brucellosis, one of us collected samples of approximately two milliliters from the sternal marrow—at the same time samples of approximately five milliliters of venous blood were obtained. Cultures were done from blood and marrow in eighteen patients, from blood alone in ten patients, from marrow alone in five patients. Samples from four patients were sterile, and samples from seven were contaminated.

The characteristic tissue reaction to invasion by Brucella is granulomatous [9, 21, 22]. This cannot be distinguished from a tubercle except by bacteriological study. Even caseation has been reported [2, 3]. Brucellosis granulomata in man are

small; the largest nodule encountered by Sundberg and Spink measured 0.5 millimeter in diameter, and the largest nodule encountered by Hamilton measured 800 micra (0.8 millimeter). The size of these nodules accounts for the failure of roentgenograms to detect bone changes in the common cases of brucellosis. Even when nodules agglomerate and erode the osseous trabeculae of the vertebrae, surrounding themselves by granulation tissue, it may not be possible from the roentgenograms to interpret accurately the changes which Brucella provoke in the spine. Pedro-Botet obtained two morbid anatomical specimens of brucellosis of the spine in which he showed, after maceration of the bone, that the Brucella lesions were more extensive than one could see in roentgenograms. Vertebrae and joints which appear apparently unaffected in roentgenograms, may nonetheless be the seat of lesions.

As in tuberculosis, the granulomatous and other changes provoked by Brucella in the spine were found to aggregate initially on subchondral bone tissue by Ciscar Rius [1]. When these tissues are eroded and destruction of the cartilaginous plate in two adjacent vertebrae occurs, the intervertebral disc that is between them loses its turgescence and can no longer keep the vertebral bodies in proper separation. Ciscar Rius examined a disc that had been devitalized in this way and found no evidence of inflammation. He found hydropic degeneration which was more marked in the annulus fibrosus than in the nucleus pulposus. Evidence of inflammation was also absent in the osteophytes which in brucellosis spondylitis grow in pairs on each side of affected intervertebral joints and tend to ankylose in bridge formation. The formation of these osteophytes appears to be analogous to the formation of osteophytes in spondylosis deformans, except that here the osteophytes form remarkably quickly—in a matter of weeks or two to three months.

Brucella in bone are apt to provoke suppuration which, as in tuberculosis, may form a cold abscess. Brucella have been cultured from these abscesses on many occasions. Furthermore, eroded vertebral bodies may collapse as in tuberculosis. Wedging of vertebrae, angulation, or tilting to a side are not uncommon. It appears that Brucella may produce compression on the cord in the same way that Seddon described for Type I Pott's paralysis [18]. Extradural cord compression from spondylitis must therefore be recognized as a cause of brucellosis myelopathy as well as meningeal vascular lesions or localized arachnoiditis. The patient in Case 6 presented peculiarities. The presence of an epidural abscess was ascertained at surgery; yet roentgenograms did not reveal any abnormality that could be attributed to Brucella. In this case hematogenous localization of Brucella in the meninges was very carefully considered, but the final conclusion favored a purulent extension from a focus in the spine too small to be detected roentgenographically. Suppuration from bone is common, but there is no mention in the literature of suppuration from primary localization of Brucella in the meninges or nervous tissue. Fasanaro collected fourteen postmortem cases of brucellosis meningo-encephalitis from the literature[5]. Dogliani added another case. In no case was suppuration found [4].

CONCLUSION

A small percentage of patients suffering from brucellosis, experience extradural cord compression from spondylitis. It is important to recognize brucellosis early in these patients. Prognosis can be good when rest and appropriate antibiotics are administered in time.

NOTE: The authors wish to thank the Chief Government Medical Officer, Malta, for permission to publish these cases.

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Cineplasty

HISTORICAL REVIEW, PRESENT STATUS, AND CRITICAL EVALUATION OF SIXTY-FOUR PATIENTS

BY ROBERT MAZET, JR., M.D., LOS ANGELES, CALIFORNIA

Cineplastic operations on amputated extremities interested few North American surgeons until the Army and Navy Amputation Centers, established during World War II, focused attention on the numerous problems of amputee rehabilitation. Fundamental studies on physiology, function, and performance of cineplasticized muscles [23] enhanced understanding of some of these problems. Improved devices and techniques provided better functioning prostheses [2, 25] than were previously available.

HISTORICAL

The father of cineplasty was Vanghetti. His initial publication on this subject appeared in 1906 [42]; and, in 1916, it was followed by a report of nineteen cases [44]. One year later, he reviewed the collected cases of several surgeons [43]. No follow-up data were given, except in a single case in which the *clava* or club motor was said to have functioned for five years. Vanghetti's surgical efforts were confined to experimental work on chickens. Ceci, inspired by Vanghetti, recorded the first skin-covered tendon loops in 1905 [12], but he did not tell how these functioned. The following year, he reported on two additional cases [11]. In these, he described how he constructed tendon loops by joining the severed ends of flexor or extensor tendons. A number of subsequent papers by Italian surgeons [13, 17, 28, 29, 31, 32] described different types of muscle motors used to activate prostheses. All claimed good results, but none included adequate follow-up studies. Putti was the first to warn against construction of multiple tunnels in a single stump; he recommended two as the maximum.

In Germany, a parallel but independent study of muscle motors occurred. Elgart in 1909 reported the first case in German literature [15]. Sauerbruch began work in this field in 1915 and the first edition of his text appeared the following year [34]. He attempted a variety of techniques directed toward the construction of skin-lined tubes which he led through muscles, in contrast to the clubs and loops preferred by the Italians.

Sauerbruch made several important contributions; these provided the basis of present-day technique and practice. He realized the inefficiency of the muscle motors used by the Italians and developed a better technique of selection. He placed his motors proximal to the bone end, in contrast to the Italian practice of constructing motors distal to the bone end. He was devoted to the idea of harnessing protagonists and antagonists to the prosthesis in order to provide more physiological and more precise movements of the terminal device in flexion and extension. He cautioned against expecting the canalized muscle to perform against too heavy loads or for protracted periods. He stressed the necessity of an adequate training program in prosthetic use. He devised a prosthesis which was superior to any then available, and provided it with a locking device to take the load from the muscle if prolonged pull against the tunnel was necessary. This was the percursor of our present elbow-lock device. Biesalski [3] contributed an exerciser and muscle stretcher for use in the training period.

Sauerbruch's disciples spread his gospel afar. His enthusiasm may have led him to overlook certain undesirable features which others noted. Burk [10], in 1917, reported that infection or scarring caused some tunnels to become bound down,

and also noted insufficient excursion in others. He concluded, as did Putti later, that scarred stumps were unsuited for Sauerbruch tunnels. Spitzy [40] constructed the first biceps tunnel in a short below-the-elbow stump. Seidler [35] stressed the necessity of constructing tunnels of sufficient size with adequate excursion. Erlacher [16], in 1918, introduced an important modification of the method of tunnel construction. He made two parallel transverse skin incisions at each end of the proposed skin tube, then constructed the tube by inverting the skin between the incisions. Anschütz [3] first described release of the distal end of the tunneled muscle to increase excursion. This technique was not generally adopted until Lebsche demonstrated its worth to the Surgeon General's Commission in 1945.[14]

Bosch Arana introduced cineplasty to South America. He reported the use of several types of muscle motors, and the use of multiple motors in an extremity [6, 7, 8] but he offered no follow-up studies.

FIG. 1

FIG. 2

Fig. 1: Ceci sling technique. Flexors and extensors are sutured together and covered by skin. (Reprinted by permission from *Cineplastic Operations on Stumps of the Upper Extremity* by Rudolf Nissen and Ernst Bergmann. New York, Grune and Stratton, 1942.)

Fig. 2: The muscle knob or *clava*. Flexor and extensor masses are shown. A leather loop about these furnished motor power. (Reprinted from "Plastiche e protesi cinematiche" by Vittorio Putti. Chir. d. Org. d. Movimento, 1: 460, 1917.)

Kessler [19,20,21] espoused cineplasty in this country for many years but there was no general response to his enthusiasm.

In reading both the early and recent literature on cineplasty, one cannot fail to be impressed by the paucity of follow-up data and of objective evaluation. The articles are fairly explicit in delineation of surgical techniques. Many contain photographs of resultant loops or tunnels, and often beautiful diagrams or drawings are included. The theoretical concepts involved are explained in detail. The immediate postoperative course and short-time functional results are recorded. Generous claims of patient benefit are enunciated but not substantiated.

The reasons for the abandonment of the early skin and tendon loops and knobs are not entirely clear. It seems evident that they did not function as efficient motors. Sauerbruch's development of a tunnel through the muscle belly resulted in the formation of a more dependable motor with which to activate a terminal device than the one that previous surgical experiments had provided.

Objections to the earlier types of clubs and tunnels probably included push-pull motion of the prosthesis on the stump, stretching of the skin tubes, irritation and excoriation of the skin from pressure of leather thongs or ivory pegs, and difficulties in tunnel hygiene. Sauerbruch's tunnels, the forerunners of present day tunnels, were designed to obviate these inadequacies.

Why was cineplasty in lower extremities abandoned? For twenty-five years there were no advocates of these tunnels, but recently Spittler and Batch [37] re-

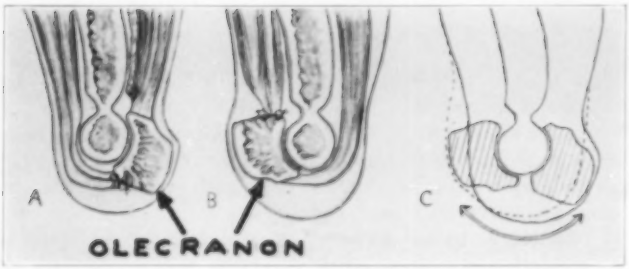

FIG. 3

The terminal end of the bone stump is activated by contraction of flexor and extensor muscle groups. (Reprinted by permission from *Cineplastic Operations on Stumps of the Upper Extremity* by Rudolf Nissen and Ernst Bergmann. New York, Grune and Stratton, 1942.)

FIG. 4

Fig. 4: A skin covered biceps-triceps loop of the Ceci type. (Reprinted from "Sulla protesi cinematica" by Riccardo Galeazzi. Riv. Ospedal. **2**: 260, 1912.)

Fig. 5: Tendon loops formed by suturing flexors and extensors of foot together. Leather thongs are seen passing through the loops. (Reprinted from "Amputations cinéplastiques des membres supérieurs" by Antonio Ceci. Presse Méd., **19**: 246, 1906.)

FIG. 5

ported an instance in which they constructed a cineplasty tunnel through the quadriceps muscle in a Gritti-Stokes end-bearing amputation stump. The patient was able to extend the prosthetic shin by contraction of the muscle. Some controversy arose as to whether or not this operative exercise was of significant benefit to the patient.

It is enlightening to note that several precepts enunciated by earlier writers on cineplasty were unheeded. These were recently re-emphasized:

1. The necessity for good skin, muscle power, sensation, and joint motion expounded by Putti [32] and Seidler [35];

2. The need for large tunnels with good excursion stressed by Seidler, Anschütz [3], and Bosch Arana [8];

3. Release of the insertion of the canalized muscle practiced by Anschütz [3];

4. The selection of patients who have the mental stability and perseverance to learn good use of prosthesis, pointed out by Nissen and Bergmann [27];

5. The desirability of protecting the suture line from pressure of the pin or peg, elucidated by Erlacher [16];

6. The necessity for an adequate exercise and training period insisted on by Putti, Sauerbruch, and Biesalski [5].

CONTEMPORARY TECHNIQUE

The only one of the several methods devised to harness muscles to prosthesis that survives is the construction of an inverted skin-flap tunnel which is passed through the body of the muscle selected for the motor. This method is based on Sauerbruch's technique. All of the articles in English record experiences with it—the early ones are universally overenthusiastic.

Present practice in tunnel construction embraces several modifications of Sauerbruch's method. Detachment of the insertion of the tunnelled muscles, advised by Anschütz [3] and Lebsche [14, 18], is customary. The central portion of the belly of the muscle rather than its distal end is generally regarded as the most favorable site for canalization [1, 2]. Sauerbruch's disciples advocated the use of the small, relatively superficial tubes just proximal to

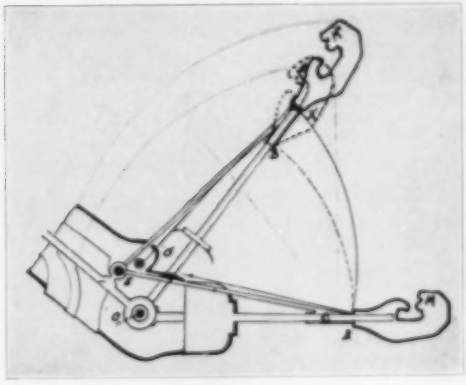

FIG. 6

FIG. 7

Fig. 6: Diagram of prosthesis attached to a biceps motor in a short forearm amputation. (Reprinted by permission from "Two Kineplastic Problems Solved" by Guillermo Bosch Arana, Delfor Del Volle, and F. Wildermuth. Surg., Gynec., and Obstet., **36**: 559-565, 1923.)

Fig. 7: Patient wearing prostheses of type shown in Fig. 6. (Reprinted by permission from "Two Kineplastic Problems Solved" by Guillermo Bosch Arana, Delfor Del Volle, and F. Wildermuth. Surg., Gynec., and Obstet., **36**: 559-565, 1923.)

muscle-tendon junction, but these have been replaced by longer tubes of greater diameter [9, 12, 23, 38, 39] and are now usually placed through the mid-portion of the muscle mass instead of in the anterior portion. Spittler [39] turns the end of the skin tube back over the muscle so that the suture line (skin graft to tube) is not subjected to pin pressure.

Among others Kessler [19], Magee [24], Mulvihill [26], Rank and Henderson [33], and Thomas and Haddan [41] favor forearm tunnels to activate terminal devices, and passive tunnels for holding the prosthesis on the stump, as being particularly valuable. Nissen and Bergmann maintain that the forearm muscles and the biceps are equally good for cineplasty. Forearm and holding tunnels are regarded less favorably by more recent writers. The advocates of these small tunnels with little force or excursion have failed to publish reliable follow-up studies supporting their contentions.

Kessler [20] believes in a waiting period of at least six weeks between amputation and cineplasty. He states that 60 per cent of forty-three children in whom cineplasty was performed were prosthesis users [21], and 66.6 per cent of 264 cinematized individuals used their prostheses daily [19]. Brav and his associates [9], in a follow-up study, mailed detailed questionnaires to former patients. The report of

FIG. 8

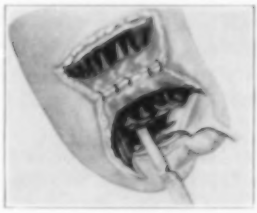

FIG. 9

FIG. 10

Fig. 8: Incisions used in construction of double-pedicle flap. (Reprinted by permission from *Cineplastic Operations on Stumps of the Upper Extremity* by Rudolf Nissen and Ernst Bergmann. New York, Grune and Stratton, 1942.)

Fig. 9: The muscle is filleted in order to bring superficial portion over skin tube. (Reprinted by permission from *Cineplastic Operations on Stumps of the Upper Extremity* by Rudolf Nissen and Ernst Bergmann. New York, Grune and Stratton, 1942.)

Fig. 10: The superficial portion of the muscle has been brought over the skin tube and sutured to the posterior portion. (Reprinted by permission from *Cineplastic Operations on Stumps of the Upper Extremity* by Rudolf Nissen and Ernst Bergmann. New York, Grune and Stratton, 1942.)

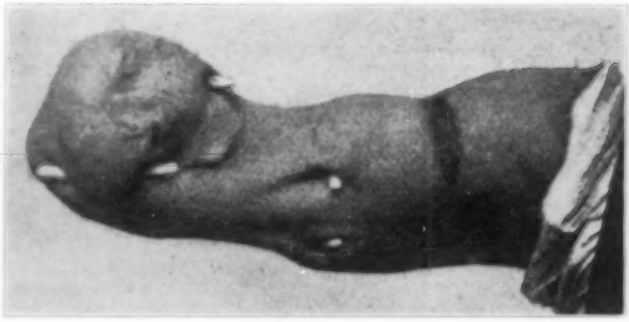

FIG. 11

The biceps, triceps, forearm flexors, and forearm extensors have been cineplasticized. (Reprinted from "Beiträge zur Behandlung der Amputationsstümpfe nach Sauerbruchscher Methode" by W. Anschütz. Münchener Med. Wochenschr., **66**: 460, 1919.)

the answers indicated that 70 per cent of the patients with biceps cineplasty used their prostheses, as did 35 per cent of those with pectoral cineplasty. Spittler [39] reports twenty-three biceps tunnels, two triceps tunnels, seven pectoral tunnels, and one latissimus dorsi tunnel. Of these thirty-three tunnels, two biceps and one triceps were failures. He regards all upper-extremity amputees with good skin and good muscles as suitable candidates for cineplasty.

Klopsteg and Wilson [23], expressing more recent views, enunciate the following criteria for selection of patients: the amputee should be a mature, well adjusted, persevering, intelligent person willing to cooperate in the postoperative training program; he should have seen others who have had cineplasty and should want a tunnel himself. Cineplasty therefore is not a primary procedure. (We believe the patient should demonstrate good use of a conventional prosthesis for six months.)

Klopsteg and Wilson [23] state that:

1. A preoperative exercise period, to strengthen the muscles of the entire extremity and fully mobilize the joints, is advisable. A postoperative training period, to be started about ten days following surgery, is mandatory. The muscle to be tunnelled must be strong, and be covered by good skin.

2. A pin or peg should be placed through the tunnel at operation, or when the wound is inspected, ten days later. This should be worn constantly.

3. The tunnel should be cleaned daily with a bland soap, and thoroughly

dried. (A cotton swab-on-stick is an excellent instrument for this.) A light application of 70 per cent alcohol may then be made, if so desired.

4. The area of skin utilized for the tunnel should be not less than three inches square, three and one-half inches if feasible. (The tunnel should admit the little finger easily.)

In addition they stress the necessity for having a competent prosthetist to fabricate the arm, and a competent trainer to teach its maximum use.

They reflect the opinion of the Advisory Committee on Artificial Limbs, with particular reference to the biceps tunnel, and state that the advantages of cineplasty are: (1) greater range of motion of the limb, (2) deep proprioceptive sensation, which helps the amputee to pinpoint the location of the terminal device, (3) better performance of fine hook or finger motions, and (4) no need for an axilla loop.

TABLE I

Cineplasty	No. of Patients	No. of Tunnels
Below-the-elbow biceps (1 bilateral)	25	26
Above-the-elbow biceps and triceps	1	2
Pectoral (1 bilateral)	10	11
Pectoral and triceps	1	2
Flexors and extensors (1 bilateral)	6	14
Extensors only	1	1
Totals	44	56

TABLE II

	Successful Tunnels	Per cent
Biceps	19 of 27	70
Triceps	0 of 2	0
Pectoral	6 of 12	50
Forearm	0 of 15	0
Totals	25 of 56	45

Slocum [36] stressed the necessity for a tunnel of sufficient diameter, and urged that it be placed as far distally as possible to provide maximum strength and excursion.

CRITICAL EVALUATION

Case Material

Recent detailed studies of the follow-ups on forty-four patients with fifty-six muscle tunnels were made by the author (Table I). The follow-up periods ranged from nineteen months to eighteen years, with one exception.

At the time of cineplasty, the age range was from eight to forty-nine years. One boy was eight, one nine, one thirteen, and one seventeen. Two were women. For the most part, however, cineplasty was performed on young, generally healthy, male veterans. These veterans were not representative of a cross section of the general population. In this group, one should encounter the greatest motivation and, therefore anticipate a higher ratio of success in the use of prostheses, than in the general population. Most of them followed sedentary occupations, but among the successful wearers, there were two heavy-equipment operators, two lumber mill hands, one welder, and one racing-car driver.

Each of these patients was examined and questioned by the author, or some other competent observer, in an effort to evaluate them for the following: ade-

quacy of surgical procedure, strength and excursion of tunnel, postoperative complications, advantage or disadvantage of cineplasty to the patient, value of post-fitting training in prosthetic use, efficiency of prosthesis, patient acceptance of prosthesis, causes of failure in unsuccessful cases, and criteria in selection of cases.

Analysis of Cases

Despite the recent improvements in surgical and prosthetic techniques the proportion of good cineplasty users among our patients was no better than that claimed in earlier reports. Of the below-the-elbow biceps tunnels there were seven

TABLE III

Causes of Failure	No. of Failures
Poor selection of patient	8
Recurrent irritation of tunnel	7
Closure of tunnel	3
Insufficient or lack of cooperation in training	8
Inadequate tunnel	9
Inefficiency of prosthesis	4
Does not need prosthesis for work	2
Dependency for tunnel hygiene (bilateral pectoral)	1

TABLE IV

Postoperative Complications (some of these are mentioned in Table III)	No. of Complications
Significant troublesome tunnel irritations	7
Re-attachment of biceps tendon to deep tissue	2
Re-attachment of biceps tendon to skin	3
Re-attachment of pectoralis insertion to humerus	1
Pectoralis insertion not detached at cineplasty	1
Gradual closure of tunnel	3
Tunnel significantly shrunk from disuse	1
Severe phantom pain	3
Tunnels of insufficient size	9 + 1 technically unacceptable

failures out of twenty-six. One patient with biceps and triceps tunnels used the biceps tunnel only. Biceps tunnels were 70 per cent successful. Of the twelve patients with pectoral tunnels, there were six users—a success ratio of 50 per cent. Both triceps tunnels and all the forearm tunnels were failures. In one patient with above-the-elbow pectoral and triceps tunnels, both failed. Of the fifty-six tunnels only twenty-five were used (Table II). This discouragingly small proportion of useful tunnels may be partly due to critical differentiation between prosthesis wearers and prosthesis users. A number of those classed as failures did wear artificial arms, but did not use their tunnels and do not believe that the operation benefitted them.

Reasons for Failure

The factors producing failure include improper selection of cases, insufficient or no patient cooperation during post-fitting training, infection or excoriation and gradual closure of skin tunnel, reattachment of tendinous insertion to deep tissue, insufficient strength and excursion of tunnel, mechanical inefficiency of prosthesis, and the ability of patient to manage without an artificial arm (Tables III, IV, and V).

Biceps Tunnels

Of the eight failures in the below-the-elbow biceps group, two were definitely due to poor selection of patients; and in two others this was a contributing factor. In these instances, the men exhibited psychopathic personalities, and failed to cooperate in learning how to use the prosthesis. One of them insisted upon wearing a non-functional hand. In one patient, reattachment of the biceps insertion on two occasions increased resistance toward learning effective use of his tunnel. He was unable to disassociate elbow flexion from biceps contraction. In the eight-year-old boy, the lack of his parents' cooperation made adequate training impossible. This eventuated in poor usage of even a conventional prosthesis. Two failures were due to a combination of factors; repeated excoriation of the tunnel with strenuous use, constant breaking of cables, and failure of the APRL hand to function properly. In two patients, repeated infection eventuated in removal of the tunnel. Two of the eight were cineplasty prosthesis wearers, but not good users. The other six wore conventional arms.

One of the failures was a thirty-three-year-old man, who requested the operation. Four years previously amputation had been performed four and one-half inches below the elbow, but he had had neither a prosthesis nor regular employment since amputation. These last two facts made us hesitant. However, he saw and talked with several users of cineplasty arms and persuaded us that he could use this type of device. We discovered too late that he was a habitual liar, and a constitutionally dependent person who lacked initiative and purpose. He disappeared five months after cineplasty. The technical procedure was flawless; the prosthesis without blemish. The error was in selection of the patient.

TABLE V

Other Data	No. of Patients
Find function of APRL hand insufficient	5
Tunnels subsequently removed	4
Tunnels secondarily enlarged	3
Release of attached tendon insertion	3

Two other below-the-elbow biceps cases deserve comment. A woman secretary, thirty years old, with a congenital, medium, below-the-elbow amputation, had had a small tunnel inserted seven years before at the age of twenty-three. A German type of arm was unsatisfactory and a new model of prosthesis was supplied two years later. She had only a one and one-half inch excursion. The short excursion, the lack of perseverance and of motivation, and a change of residence, 1,500 miles away, combined to make her a non-user. She was classified as a failure. Dr. Clinton Compere later secured a new prosthesis for her and trained her in its use. She gained a better outlook and was restored to the group of successful wearers despite her small, not too efficient, tunnel. The other was a man on whom a medium, below-the-elbow amputation had been performed two years after an acid burn of forearm and hand. He had many emotional problems and made a poor initial adjustment. His first request for a muscle tunnel was refused. A change of employment, acceptance of family responsibilities, and acquaintance with three good cineplasty prosthesis wearers changed his and, later, our outlook on his problem. Cineplasty was done, two and one-half years after amputation. He was still a good wearer after twenty-three months. This successful outcome was thought to be due to his emotional growth and maturity in facing his problems.

The failures of the two triceps cineplasties were due to constant irritation of the tunnels when they were employed, despite good technical surgery in each instance. These tunnels were abandoned.

Pectoral Tunnels

Failures in the pectoral tunnel group were ascribed to multiple causes in some instances. Two men could never use the tunnels because of constant irritation. The hirsutism of one caused repeated hair-follicle infection within the tunnel. These tunnels closed at the lower end. The hairy tunnel was removed. In the other patient, the tunnel was reopened; afterward it almost closed again. In one patient, a poor selection because of emotional instability, the tunnel was too small and the pectoral insertion was not released originally (this was done secondarily). The patient did not cooperate in the training program. He never developed sufficient strength or excursion for good terminal-device operation. In a second emotionally unstable man, with well constructed tunnels, similar lack of cooperation vitiated all training efforts. One man tried for one and one-half years to use his tunnel but finally gave up because of constant breakdowns in the tunnel. One patient, a twenty-eight-year-old, stable, mature architect, felt no need for a prosthesis in his work. He had a six-inch stump with normal shoulder and scapulothoracic motion, and a technically excellent tunnel. He wore a hand occasionally for cosmesis.

In the bilateral amputee, a well adjusted, self-supporting insurance agent, the principal cause for rejection was the impossibility of independence in tunnel hygiene. Rotation of the prostheses and mechanical failure were contributory. One tunnel was removed. At the time of writing, he wanted the second taken out.

The pectoral tunnel in one true shoulder disarticulation, classified as successful because the patient is pleased with its function as an elbow-lock activator, was not technically satisfactory. It was a superficial, weak tunnel, with a diameter of half an inch, an excursion of one and one-half inches, and a width of five-eighths of an inch. It worked at maximum capacity in elbow-lock operation. His initial prosthesis was a Fitch arm. The tunnel activated a Dorrance #7 hook, but irritation caused abandonment of the tunnel until it was reharnessed to the elbow-lock.

The avowed purpose of the cineplasty tunnel is graduated control of the prehension device. The pectoral tunnel does not always realize this aim. Force from the tunnel must be transmitted by a cable around a corner to the terminal device. In some instances there is sufficient friction for this pull to rotate the prosthesis internally. The result is a comparative lengthening of the cable, demanding greater excursion of the tunnel than the patient can provide, to operate the terminal device. The tunnel then fails in its primary purpose. Activation of the terminal device must be abandoned in favor of control of the elbow-lock device which does not cause the prosthesis to rotate. For this purpose the pectoral tunnel is satisfactory, as it usually has greater strength and excursion than is needed for elbow-lock operation.

Three of the patients with pectoral cineplasty used the tunnels to activate the terminal device, the others to activate the elbow-lock. The six patients in whom the results were judged successful were active tunnel users who felt that terminal device or elbow-lock operation by the muscle motor was advantageous to them and who had no trouble with the tunnel.

If one adopts the more stringent standard, admitting success only in those patients who activate the terminal device by the muscle motor, the percentage of users among the pectoral group is reduced from fifty to twenty-five. Most of the patients in this review had tunnels made while in military service and prior to any prosthetic fitting. An opinion as to when cineplasty should be done is later stated.

Surgical Reclamation

Of the complications which are frequently observed, two are amenable to surgical correction. The tunnel orifice can be reopened when it becomes contracted or obliterated by scar contraction; this was done in two instances. The muscle can be freed when the distal end of the muscle becomes bound down by scar, limiting excursion; this was performed three times.

Financial Considerations

Since cineplasty is entirely elective, the financial aspects should be weighed when advising patients regarding this procedure. Hospitalization lasts about five days, but usually the patient will be away from work two or three weeks. Although rehospitalization is rarely indicated if tunnel excoriation should develop, more out-patient visits would be necessary. A new prosthesis will have to be provided, which will entail two or three weeks of additional training.

In greater Los Angeles, there are 151 upper-extremity amputees among veterans. Of these, six had cineplasty performed. No accurate statistics as to the percentage of the general amputee population having muscle motors exists.

At the Regional Office of the Veterans Administration in San Francisco, California, Dr. Neil P. McCloy examined twenty patients on whom cineplasty was performed. He has generously consented to permit our using his findings in this report:

The muscle tunnels of Dr. McCloy's patients were distributed as follows:

Cineplasty	*No. of Patients*
Below-the-elbow amputees with biceps tunnels	11
Above-the-elbow amputees with biceps and triceps tunnels	1
Above-the-elbow amputees with pectoral tunnels	5
Below-the-elbow amputees with flexor and extensor tunnels	3
Total	20

Adding these cases to the first forty-four analyzed in Tables I through V there are sixty-four patients with eighty tunnels.

The distribution of these is as follows:

Cineplasty	*No. of Patients*
Below-the-elbow biceps (1 bilateral)	36
Above-the-elbow biceps and triceps	2
Above-the-elbow pectoral (1 bilateral)	15
Pectoral and triceps	1
Flexors and extensors (1 bilateral)	9
Extensors only	1
	64

In one of Dr. McCloy's patients, a pectoral tunnel was removed because of constant excoriation. The causes of failure and the postoperative complications in McCloy's patients on the whole parallel those previously enumerated. The necessity for careful selection of patients and for adequate post-fitting training is also borne out by his series.

There were in the entire group: eleven failures in thirty-nine biceps tunnels—a success ratio of 72 per cent; eight failures in seventeen pectoral tunnels—a success ratio of 53 per cent; the triceps tunnels and all the forearm tunnels were failures. The over-all success ratio in this combined series is 46.3 per cent.

Advantages of Cineplasty

The principal advantages of cineplasty to the patient are known: freedom from constricting harness, a greater area in which useful terminal device function is possible, restoration to the patient of part of his deep proprioceptive muscle sense, and a feeling that the prosthesis is more an integral part of himself.

SUMMARY

Cineplastic muscle tunnels and prostheses, made according to present technological methods in selected patients are generally adequate. Causes of failure

in cineplastic prosthesis wearers are many, and in given instances there may be several. Those encountered in this series were, in order of their importance:

1. Injudicious selection of candidates.

2. Lack of patient cooperation in learning to use the prosthesis (as a corollary to 1).

3. In the forearm the technical impossibility of constructing muscle tunnels with sufficient strength and excursion.

4. Recurrent excoriation of tunnel skin, with resulting narrowing and, sometimes, closure of the skin tube orifice.

5. Rotation of prosthesis on shoulder when tunnelled muscle is contracted.

6. Insufficient transmission of force through cable system.

7. Limitation of excursion because of re-attachment of severed distal end of canalized muscle to deep tissue.

8. Patients' lack of real need for a prosthetic device.

Prerequisites for successful use of cineplasty tunnels are:

1. A mature, intelligent, well adjusted patient. In general he should not be engaged in heavy labor. He should have observed others who have had cineplasty, and ask for the operation. He should have exhibited good use of a conventional device for six months. Only in exceptional circumstances should cineplasty be done before the patient is fifteen years old.

2. A competent prosthetist who will make a well functioning and properly fitted device is essential.

3. Preoperatively, an adequate program of joint mobilization and muscle strengthening, and postoperatively, training in post-fitting prosthetic use is mandatory.

4. When a biceps tunnel is contemplated, an amputation stump should be well muscled, covered by good skin exhibiting normal nerve innervation, and there should be relatively normal shoulder motion.

5. Daily tunnel hygiene.

We believe that, had each of the patients reviewed in this series been screened by a prosthetic team, a number of operations which were profitless to the patient would have been avoided.

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Sciatica and the Intervertebral Disc

An Experimental Study

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Whilst the so-called disc syndrome is a well established clinical entity there does not appear to be any experimental evidence showing that a herniated nucleus pulposus pressing on a lower lumbar-nerve root does in fact cause sciatica.

Inman and Saunders commented on the conception that sciatica is caused solely by pressure on the nerve root and said that this is not borne out by the existing experimental evidence on the effects of nerve pressure, and that there is no experimental evidence to indicate that pressure alone upon the nerve root initiates pain of this characteristic type. Kelly stated: "The pressure theory of pain has come to occupy its present position largely by default. It has never been challenged, though it never has been proved. It has come to be accepted as self-evident that the common stimulus for pain is pressure or tension on nerve fibrils and free endings. . . . The evidence suggests that pressure on nerve roots is not a common primary cause of sciatic pain."

The experiments and investigations about to be described were performed in an endeavor to prove that a disc pressing on a lower lumbar-nerve root causes sciatica. Apart from this main consideration a number of ancillary investigations were carried out and will be described.

EXPERIMENTS

Series A

From a series of twenty-two patients with sciatica due to intervertebral-disc pressure eight were chosen. Each of these had classic sciatica and in each an unequivocal disc herniation pressing on the fifth lumbar and first sacral roots was demonstrated at operation. The disc material was removed through a small aperture cut in the ligamentum flavum. An effort was made to center this aperture directly over the protruding disc. When the disc material was removed, a loop of nylon thread was passed around the involved root and its two ends brought to the surface (Fig. 1). It was so placed that when the slack was taken up, the loop pressed on the root at the same place as the disc had. It tended to maintain this relation to the root because of its passage through the small aperture in the ligamentum flavum directly above. It was hoped that, by pulling on this nylon thread in order to bring it in contact with the root, the effects of disc pressure would be closely simulated.

The experiment was performed on the first postoperative day in three patients, on the fourteenth day in one, and on the tenth in the remaining four. In all these eight patients symptoms were completely relieved by removal of the disc.

Series B

There were eighteen patients in this series, thirteen of whom, at operation, showed definite disc herniation. No herniation was found in the other five but the roots were bound down by adhesions. A procedure identical with that of Series A was adopted but with some additions.

In five patients, a loop of nylon thread was passed through the dura mater and brought to the surface alongside the loop around the root. In the spinal canal it was about half an inch distant from the root loop.

In six patients a nylon loop was passed around two roots, in five, the first sacral and fifth lumbar, and in the other, the third and fourth lumbar. In the remaining seven, a procedure similar to that in the first series was followed but additional roots were tested. Testing was performed at periods varying from one to ten days after operation.

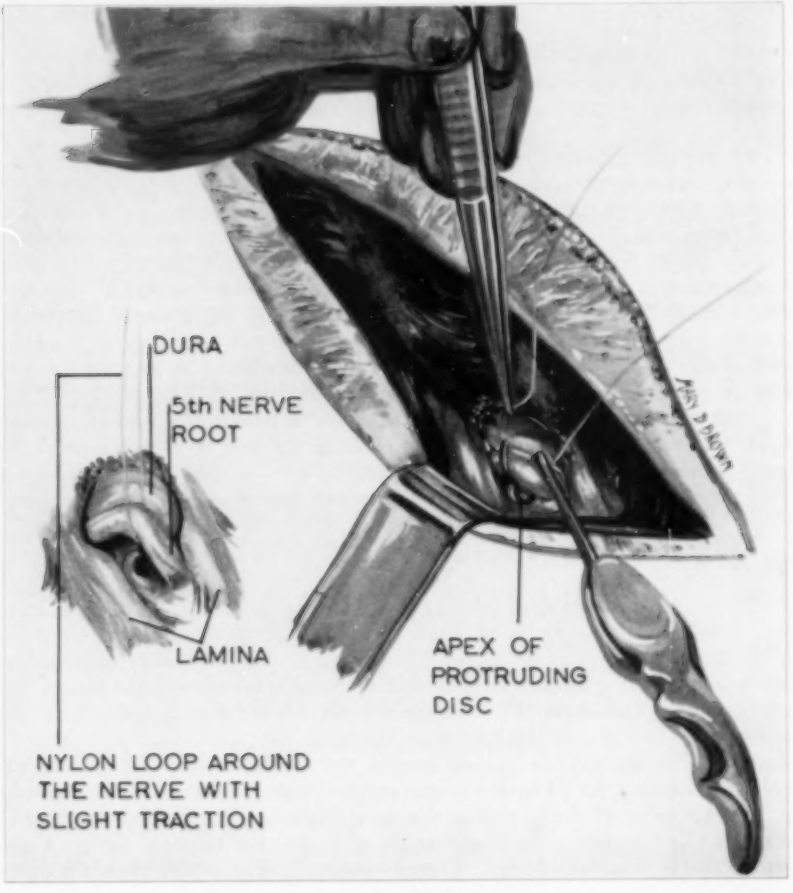

FIG. 1

Case 7. Drawing made at operation.

Series C

There were eleven patients, ten with herniated discs. Instead of testing a nerve root or the dura mater, the ligamentum flavum, interspinous ligament, and the annulus fibrosus were tested. In eight patients, one nylon suture was passed through the ligamentum flavum and one through the interspinous ligament. In two patients, the ligamentum flavum was tested; in the last the annulus fibrosus alone was tested.

In all patients, the nylon was led through a small hole in the dressing and wrapped in sterile gauze. It could thus be manipulated without disturbing the

wound. It must be stressed that there was no question of traction on the nerve root; just a gentle pull was exerted to bring the nylon in contact with it, causing a moderate degree of pressure. The amount of pressure on the root could be gauged by the fact that only a shallow groove was made on the pulp of the finger used to exert the pull. There was no suffering for the patients. The purpose of the experiment was explained to them and they all took a cooperative and intelligent part in the proceedings. Indeed some asked to have the root stimulated repeatedly so that they could more accurately localize the pain. Nevertheless, it could not be described as an enjoyable performance and a comprehensive range of investigations was not carried out on each patient. The scope of enquiry in each was set in advance and adhered to.

The cases will be reported on in the following order: first, all the cases in Series A, followed by the five cases from Series B, in which the root and the root and the dura were tested. After this come the cases of Series C. At this stage, it was considered that the major object of the experiments had been achieved. The last thirteen cases report the results of stimulating the third, fourth, and fifth lumbar-nerve roots and the first sacral-nerve root inclusive.

FIG. 2

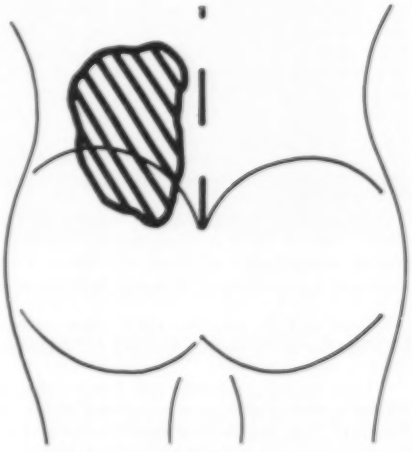

FIG. 3

Fig. 2: Case 9. Drawing with area marked where ache was felt when the dura mater, on the region of the left first sacral-nerve root, was stimulated.

Fig. 3: Case 12. Drawing is marked to show position of diffuse ache felt when dura mater was stimulated. The pain disappeared when stimulation ceased and could be reproduced at will.

SERIES A

CASE 1. R.S., sciatica, right lower extremity. At operation a disc herniation was present which pressed on the first sacral-nerve root. It was a bulbous protrusion and pressed on the anterior aspect of the root. The disc material was removed and the nylon loop placed in position at the site of root compression. When the nylon was pulled on, the root could not be drawn backwards as far as the lamina, and only a barely perceptible movement of the dura mater could be observed. The thread pressed on the anterior and lateral aspects of the root. The wound was closed and the nylon thread, wrapped in sterile gauze, was fixed on the surface of the dressing. It could then be manipulated without disturbing the wound. Thirty-six hours after operation there was complete relief from sciatic pain.

The patient was then turned on the left side, the nylon thread was exposed, and a gentle pull exerted on it. The effect was immediate. The patient jumped and exclaimed that a severe pain shot into the right buttock. It disappeared at once when the nylon was relaxed. At the second attempt the thread was very slowly drawn upon until the patient could feel pain. This time it was not so intense; the thread could be barely touching the root. Then tension was increased and as it mounted severe pain spread from the center of the right buttock down the center of the back of the right thigh, veered laterally to the

region of the biceps tendon, skipped the side of the knee, and was felt intensely on the lateral side of the calf. It ended about three inches above the lateral malleolus. The patient described the pain as having exactly the same character as that experienced before operation, but more severe. It appeared to consist of two components; a sharp pain which ran, as if along a line, down the extremity, and a deep, boring, aching, unpleasant sensation felt diffusely in the soft tissue.

The straight-leg-raising test was performed. In the absence of root irritation, the limb could be flexed to an angle of 50 to 60 degrees without pain. With thread irritation, however, any attempt to move the limb caused such an exacerbation of pain that the leg could barely be raised at all.

The effect of root pressure on skin sensation was next tested. After a continuous but gentle pull for a quarter of a minute, the patient volunteered the information that all of the toes and part of the dorsum of the foot, proximally, felt numb. It was not possible to test sensation objectively as pain was too sharp to allow the patient to cooperate.

The nylon was then removed simply by cutting one end of the loop close to the wound and pulling it out. Even this gentle action caused a stab of pain in the limb.

Case 2. J.S., sciatica, right lower extremity. At operation a large disc protrusion was present which pressed on the right fifth lumbar-nerve root. On the first postoperative day, sciatica was completely relieved.

When the loop was pulled on, an almost identical series of events occurred. This time, however, the pain stopped at mid-thigh and then reappeared on the lateral side of the calf over a small (three by two inches) elliptical area. The pain and its distribution was the same as that felt before operation. Straight leg-raising could be accomplished to an angle of 30 to 35 degrees without discomfort, but with a pull on the nylon, pain was so intense that the limb could hardly be moved at all, and it was not possible to measure the range in degrees. A pull on the nylon for a quarter of a minute caused subjective numbness in the toes.

Case 3. J.F.D., sciatica, right lower extremity. At operation a moderate sized disc was found pressing on the right fifth lumbar-nerve root. On the first postoperative day sciatica was relieved.

Root stimulation with the nylon loop caused a series of events similar in every way with those of Case 1. Preoperative sciatica was reproduced. The results of straight leg-raising were similar to those of Case 1. Pulling on the loop for fifteen seconds, however, produced a sensation of pins and needles in the toes.

Case 4. G.S., sciatica, right lower extremity. There was a disc pressing on the right fifth lumbar-nerve root. Experimental findings were identical with the previous case.

Case 5. R.P., sciatica, left lower extremity. At operation there was a large disc protrusion pressing on the anterior and medial side of the fifth lumbar-nerve root, pushing it laterally. The root was wedged between the disc and the lateral wall of the spinal canal. Compression was severe. Unfortunately, when the disc was removed, the root was crushed by a forceps. When, at operation, the root was pulled on by the nylon, it tented up slightly but the dura mater did not move. On the tenth postoperative day when traction was exerted on the nerve root the only effect was an ache in the region of the wound. There was no suggestion of sciatica. On prolonging the pull for a quarter of a minute, a subjective sensation of numbness was produced in the lower lateral portion of the buttock of the left side. On the whole, the findings were largely negative. The straight leg-raising could be accomplished to 50 degrees without discomfort whether the root was being stimulated or not. There was no motor weakness or sensory loss in the leg as a result of the crushing of the root at the time of operation. There was complete relief.

Case 6. H.H., sciatica, left lower extremity. The fifth lumbar-nerve root was bound down to a diffuse disc bulge. When the nylon was *in situ* and traction was exerted, the root tented up but did not come near the lamina posteriorly. The dura mater did not move. On the tenth postoperative day sciatica had completely disappeared but was reproduced exactly, although in a more intense form, by stimulating the root with the nylon thread. It was a dull aching pain, myalgic more than neuralgic in character.

The straight-leg-raising test was strongly positive at an angle of 30 degrees on the affected side during root stimulation. In the absence of stimulation the leg could be raised comfortably to 60 degrees. With traction on the root the right leg was then tested. It could be raised to an angle of 35 degrees, but it was difficult to assess the significance of the test on this side as pain was so severe with root stimulation that any movement of the body caused an exacerbation of pain. An attempt was made to assess muscle power while sciatica was being caused. There did not appear to be any diminution in power and the ankle and knee reflexes did not change from the normal.

FIG. 4

FIG. 5

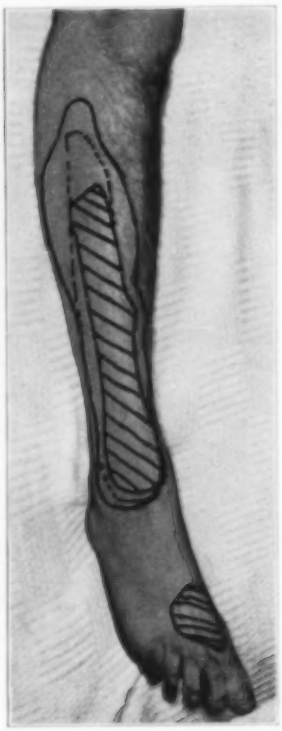

FIG. 6

Fig. 4: Case 25. Drawing with hatched lines showing radiation of pain when the third lumbar-nerve root was stimulated.

Fig. 5: Case 26. The crossed line on this photograph indicates the radiation of pain on stimulation of the left fourth lumbar-nerve root. The hatched area shows the loss of pain sensation after pressure on the nerve root.

Fig. 6: Case 28. Photograph of right leg with lines drawn to show loss of pain sensation from pressure on the first sacral-nerve root. The hatched areas indicate the preoperative loss. Postoperatively the loss extended to the area between the broken line, and with pressure on the nylon thread, to between the continuous line.

A prolonged stimulation of half a minute caused subjective numbness in the left buttock and objective diminution of sensation to pin prick over a small area two by three inches on the lateral margin of the same buttock.

CASE 7. J.B., sciatica, left lower extremity. There was a small nodular disc protrusion pressing on the fifth lumbar-nerve root (Fig. 1). Its apex lay at the center of the anterior part of the nerve and the latter was bound to the protruding disc by a number of adhesions. Pressure on the root, however, did not appear to be great.

When the nylon thread was in position and a pull exerted on the nerve, tenting was observed but the root could not be made to touch the lamina posteriorly. A barely perceptible movement of the dura mater occurred.

On the tenth postoperative day sciatica was completely relieved and straight leg-raising could be accomplished to an angle of 90 degrees without pain. There was no sensory or motor change as a result of the operation.

A slight pull on the nylon loop caused severe pain in the back of the thigh, buttock, and lateral side of the calf. It took a second or two for the pain to reach the calf, a feature which was observed in all of the other patients in whom sciatica was produced. In this patient pain appeared to spread along a narrow path down the back of the thigh. It was not possible to elicit whether it was neuralgic or myalgic in character although its distribution suggested a neuralgic type of pain in the thigh and the myalgic in the calf. On prolonging stimulation for a quarter of a minute, continuous pain was caused and was described by the patient as being exactly like that experienced before operation.

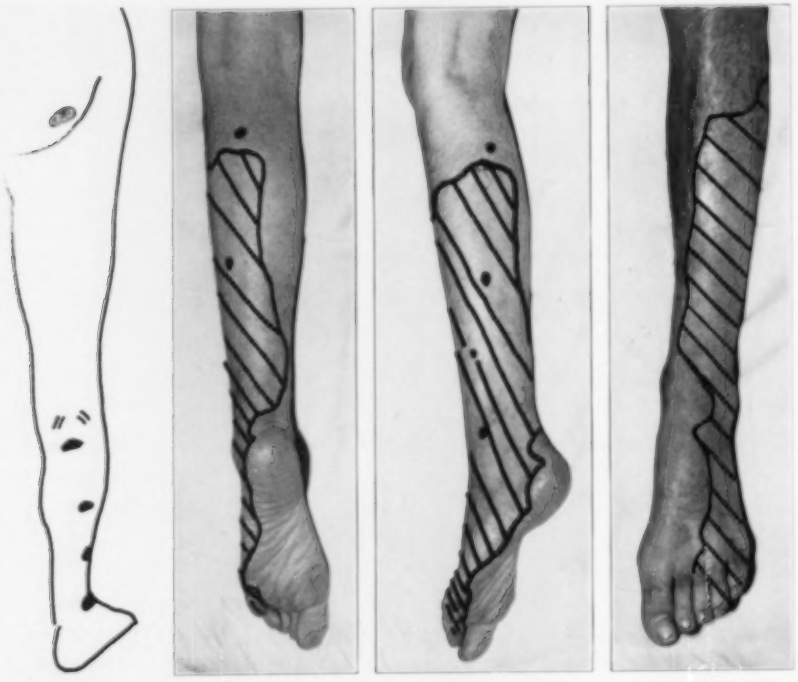

FIG. 7-A FIG. 7-B FIG. 7-C FIG. 7-D

Fig. 7-A: Case 29. The marks on this drawing show the unusual distribution of pain on stimulation of the first sacral-nerve root.

Figs. 7-B, 7-C, and 7-D: Photographs of the left leg. The hatched lines show the area of sensory loss following removal of a disc which pressed on the left first sacral-nerve root. The dots show the sites of the pain produced in the calf by stimulation of the nerve root. This atypical pain production, postoperatively, was exactly the same as that experienced preoperatively.

With stimulation there were no subjective or objective sensory changes in the limb, no paraesthesiae, and motor power was unimpaired.

With a slight pull on the root the straight-leg-raising test was strongly positive at 20 degrees on the affected side. On the opposite side the leg could be flexed to 70 to 80 degrees with ease. The pain caused by this maneuver on the left lower extremity was an intensification of the existing pain—an acute sciatica.

Electromyographic studies were carried out on this patient during root traction. The report read: The left gastrocnemius and glutaeus maximus muscles showed normal muscular activity. A little irregular unsustained spontaneous motor-unit activity was found in the left gastrocnemius. Both muscles were sampled while pain was induced by pulling on a nylon thread around the left fifth lumbar-nerve root. In no case was there any significant increase in motor-unit activity during the pain, and there was no muscle spasm. There was no evidence that root traction was producing pain through the mechanism of muscular spasm or contraction.

CASE 8. A.J.W., sciatica, left lower extremity. At operation there was a small nodular herniation touching the fifth lumbar-nerve root which lay mainly on the medial side of the disc. The nerve root was quite free, there were no adhesions, nor did there appear to be any pressure.

With nylon traction, the nerve root could be drawn backwards so as to touch the superior margin of the laminectomy opening. It seemed inconceivable that the disc could have displaced the nerve root so far posteriorly, as there was a distance of one centimeter between the dorsum of the root as it lay on the disc and lamina. There was not enough disc material to have caused so much root displacement. The dura mater showed a barely perceptible movement with nerve-root traction.

On the tenth postoperative day sciatica was completely relieved. There was subjective numbness on the dorsum of the second toe.

Traction on the nylon thread repeated the preoperative pattern of pain in every respect.

TABLE I

COMPARISON BETWEEN THE RESULTS OF NERVE ROOT AND DURAL STIMULATION

Case	Result of Stimulation of Dura Mater	Result of Stimulation of Nerve Root
9	Slight ache; virtually insensitive	Sciatic pain
10	Slight pain which disappeared	Sciatic pain
11	No pain; insensitive	Severe pain
12	Ache in lower lumbar region	Sciatic pain
13	Insensitive	Sciatic pain

The straight-leg-raising test was strongly positive at 30 degrees during stimulation but negative at 70 degrees when stimulation ceased. In the unaffected limb the test was negative at 70 degrees during stimulation.

With a continuous gentle pull on the root for a quarter of a minute, no definite sensory changes could be detected. Motor power, however, did appear to be impaired, and there was difficulty in dorsiflexing the foot. It was hard to assess whether this difficulty was due to a real muscle weakness or simply arose from fear of making the pain worse.

SERIES B

CASE 9. P.C., sciatica, left lower extremity. At operation there was a cone-shaped herniation pressing on the anteromedial aspect of the first sacral-nerve root and pushing it posteriorly so as to compress it against the lamina.

A nylon loop was passed around the involved nerve root and another finer nylon loop was passed through the dura mater close to the root. Both loops were brought to the surface and dealt with as in previous experiments. By this method it was now possible to compare the effects of pulling on the dura mater and on the nerve root.

After operation sciatic pain was completely relieved and five days later testing was performed. On pulling the dural thread, an ache was felt at the medial and inferior aspect of the left buttock just at the fold (Fig. 2). It was localized to an area about one inch in diameter and was of a mild nature. It contrasted strongly with the sharp darting pain caused when the loop around the nerve root was pulled on. The dura mater appeared to be virtually insensitive, the nerve root hypersensitive. The dural thread was pulled a second and third time, but the patient was scarcely aware that anything was being done. Nerve-root stimulation caused sciatic pain exactly like that present before operation.

CASE 10. E.H., sciatica, left lower extremity. At operation there was a large dome-shaped herniation pressing the anterior aspect of the fifth lumbar-nerve root. The root was not compressed against the lamina. Pulling on it with the nylon thread caused the dura mater to move slightly. The involved nerve root was much more sensitive to the touch than the first sacral-nerve root. A loop of nylon was passed around the fifth lumbar-nerve root and another through the dura mater about a half an inch away.

There was complete relief from sciatica the day after operation, and a few days later testing was carried out.

The result of traction on the dura mater was pain in the back of the center of the thigh halfway down and in the calf. This gradually disappeared and with repeated stimulation, less and less pain was felt, until eventually none was caused.

The result of stimulation of the nerve root was immediate, sharp, lancinating pain. The preoperative pain pattern was reproduced.

CASE 11. X.G., an elderly man, had intractable pain. This was a somewhat different case. The patient was having a chordotomy done under local anaesthesia and the opportunity was taken of testing the dura mater for sensation and of stimulating an anterior and posterior nerve root. A loop of nylon thread was passed around the anterior root of the fourth thoracic nerve and was brought in contact with the nerve. It caused severe and diffuse pain in the region of the right shoulder and scapula. A similar procedure was adopted for stimulation of the posterior root of the fourth thoracic nerve. Much more severe pain was caused. A mere touching of the nerve root caused widespread acute gripping pain in the region of the right shoulder. The dura mater was gripped with a forceps, then pulled on strongly. The patient was virtually unaware of either of these procedures.

CASE 12. A.L., sciatica, left lower extremity. At operation there was a large disc herniation compressing the first sacral-nerve root against the lamina, posteriorly. The disc was

removed, and the two loops of nylon were placed *in situ* as before. There was complete relief from pain.

Nerve-root stimulation reproduced the preoperative pattern of pain exactly. Traction on the dura mater caused what was described as a slight but vague ache in the lower left lumbar region (Fig. 3). It could not be defined precisely and might be described more accurately as a mild form of discomfort.

CASE 13. E.K., sciatica, left lower extremity. There was a conical disc protrusion just touching the fifth lumbar-nerve root. The disc was removed, and the nylon thread was placed in position as before. Symptoms were relieved.

On the second postoperative day the nerve root and dura mater were tested with results virtually identical with those in the previous four patients. The dura mater did not appear to be sensitive to traction. Stimulation of the root caused sciatic pain similar to that experienced before operation.

A summary of these findings is given in Table I.

SERIES C

The next eleven patients all had disc herniations involving either the first sacral-nerve root or the fifth lumbar-nerve root. Each was dealt with in the appropriate way and attention then directed to the ligaments. In eight of them a nylon suture was passed through the ligamentum flavum and interspinous ligaments. In two, only the ligamentum flavum was tested, and in the final one the annulus fibrosus alone.

In the case of the ligamentum flavum either the fourth interlaminar or the lumbosacral space was chosen. This applied equally to the interspinous ligament. In the final one the annulus fibrosus, at the site of the lesion, was tested.

CASE 14. J.E., sciatica, right lower extremity. At operation there was a disc protrusion involving the first sacral-nerve root. A nylon suture was passed through the ligamentum flavum between the fifth lumbar lamina and the sacrum and another through the deep part of the ligamentum interspinalium. Each was brought to the surface as previously described.

On the tenth postoperative day testing was carried out. Traction was exerted on the ligamentum flavum; and, after pulling fairly hard for a few seconds, a dragging sensation was felt deep in the back in the region of the wound. It was not painful. When traction ceased the dragging sensation remained for half a minute and then disappeared. The patient could not say exactly when the pull on the nylon thread had stopped. When traction was again exerted the same series of events took place. When traction was exerted on the interspinous ligament, some pain was caused but it appeared to be associated with the movement of the nylon thread in the wound. When a steady pull was maintained, the patient was virtually unaware of what was happening.

CASE 15. C.H., sciatica, right lower extremity. Disc protrusion involved the first sacral-nerve root. There was complete relief from pain after the operation and testing was performed on the eleventh postoperative day.

The ligament between the fifth lumbar lamina and sacrum was tested by traction. Slight pain was caused in the back, in the region of the wound, and at the upper medial part of the buttock on the right side. It took a few seconds for the pain to appear and, when traction ceased, a few more for it to disappear. On the whole it could scarcely be described as pain. The interspinous ligament at the same level as the ligamentum flavum was also tested by traction. There was no pain and the patient was unaware that anything was being done.

CASE 16. J.H., sciatica, left lower extremity. There was a disc prolapse involving the fifth lumbar-nerve root. The nylon was placed *in situ* between the fourth and fifth laminae and between the fourth and fifth spinous processes.

On the tenth postoperative day, traction was exerted on the ligamentum flavum. At first the patient felt a dull vague ache at the back of the left knee. It lasted a few seconds and then disappeared. Subsequent repeated pulls on the nylon caused no pain; the ligament appeared to be insensitive. No pain was caused when traction was exerted on the interspinous ligament, and the patient was not aware of anything.

CASE 17. J.C., sciatica, right lower extremity. There was disc herniation involving the fifth lumbar nerve.

TABLE II

RESULTS OF STIMULATING THE INTERSPINOUS LIGAMENTS, LIGAMENTUM FLAVUM, AND THE ANNULUS FIBROSUS

Case	Interspinous Ligament	Ligamentum Flavum	Annulus Fibrosus
14	Insensitive	Dragging sensation	
15	Insensitive	Slight ache in back	
16	Insensitive	Insensitive	
17	Insensitive	Slight dragging sensation	
18	Insensitive	Insensitive	
19	Slight dragging sensation	Vague ache	
20	Insensitive	Insensitive	
21	Insensitive	Insensitive	
22	Insensitive	Insensitive	
23	Insensitive	Insensitive	
24	Insensitive	Insensitive	Backache in lower lumbar region

Nylon thread was inserted *in situ* between the fourth and fifth laminae and corresponding spinous processes. There was complete relief from pain after the operation.

Testing was performed on the tenth postoperative day. When traction was exerted on the ligamentum flavum a barely perceptible sensation of drag was experienced. There was no pain; the ligament appeared to be insensitive. No pain was caused when traction was exerted on the interspinous ligament. The patient was completely unaware of what was being done.

CASE 18. L.E., sciatica, left lower extremity. There was disc herniation involving the fifth lumbar-nerve root.

Nylon thread was inserted *in situ* at the fourth and fifth interlaminal space and the corresponding interspinous space.

There was complete relief of pain following the operation and testing was performed on the tenth postoperative day. There was no pain or discomfort when traction was exerted on the ligamentum flavum. The patient was unaware that anything was being done. Traction exerted on the interspinous ligament showed that the ligament was insensitive.

CASE 19. J.H. sciatica, left lower extremity. There was a disc lesion involving the first sacral-nerve root. Nylon thread was inserted *in situ* at the fourth and fifth interlaminal space and the corresponding interspinous space.

Pain was relieved by the operation, and testing was performed on the tenth postoperative day. When traction was exerted on the ligamentum flavum, a slight but vague ache was caused in the region of the wound. Traction on the interspinous ligament caused a slight dragging sensation.

CASES 20, 21, 22, and 23 were dealt with in a similar way. No fresh information was obtained; both ligaments appeared to be insensitive.

CASE 24. G.S., sciatica, right lower extremity. No definite disc herniation was found; but the lumbosacral intervertebral space was explored, and a nylon loop was passed through the annulus fibrosus and posterior longitudinal ligament. Traction was exerted on these structures the day after operation. There was no pain or discomfort; just an awareness that something was being done. On maintaining a continuous pull for about half a minute, backache in the lower portion of the lumbar spine was caused. It was described by the patient as "an ordinary backache."

In Table II a summary of these findings is presented.

PAIN PATHWAYS AND SENSORY CHANGES IN FIFTH LUMBAR TO FIRST SACRAL-NERVE ROOTS INCLUSIVE

In the last thirteen patients, an effort was made to map the pain pathways and sensory changes following stimulation of the third, fourth, and fifth lumbar-

TABLE III

REFLEX AND MOTOR CHANGES FOUND POSTOPERATIVELY AND AFTER PRESSURE ON THE NERVE ROOT AND DURA MATER

Case	Untouched			Stimulation of Dura Mater			Sacral or Lumbar-Nerve Root	Pressure on Nerve Root			Comment
	Motor Power	Knee Reflex	Ankle Reflex	Motor Power	Knee Reflex	Ankle Reflex		Motor Power	Knee Reflex	Ankle Reflex	
9 Test 1	Full	+	Absent	Full	+	Absent	S 1	Full	+	Absent	No change
Test 2 (6 days later)	Full	+	Absent				S 1	Full	+	Absent	No change
10	Weakness, extensor hallucis longus?	+	Absent	Weakness, extensor hallucis longus?	+	Absent	L 5	Definite weakness, extensor hallucis longus	+	Absent	Stimulation of fifth lumbar-nerve root accentuated weakness of extensor hallucis longus
12	Full	+	Absent	Full	+	Absent	S 1	Full	+	Absent	No change
13	Weakness, dorsiflexors of toes	+	Absent	Weakness, dorsiflexors of toes	+	Absent	L 5	Weakness, dorsiflexors of toes	+	Absent	No change
34	Full	+	Absent				S 1	Full	+	Absent	No change
33	Slight weakness, extensor hallucis longus	+	+				S 1	Slight weakness, extensor hallucis longus	+	+	No change
30	Full	+	Absent				S 1	Full	+	Absent	No change

FIG. 8

FIG. 9

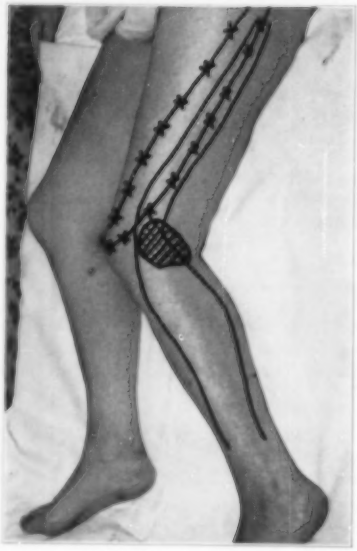

FIG. 10

Fig. 8. Case 30. Hatched lines in photograph of left thigh show the radiation of pain produced by stimulating the left first sacral-nerve root. This pain reproduced preoperative pain. No sensory changes could be produced.

Fig. 9: Case 31. Hatched lines in drawing indicate the area of sensory loss following pressure on the first sacral-nerve root.

Fig. 10: Case 32. The crossed lines on the photograph outline the area where pain was felt on stimulation of the third lumbar-nerve root. The continuous lines outline the pain area on stimulation of the fourth lumbar-nerve root. The hatched lines indicate area of loss of pain sensation following pressure on the fourth lumbar-nerve root. There was no loss of sensation from pressure on the third lumbar-nerve root.

nerve roots and the first sacral-nerve root. In four patients the effects of stimulating the first sacral-nerve root were compared with the effects of stimulating the fifth lumbar-nerve root in the same patient. In the same way the effects of stimulating the third lumbar-nerve root was compared with the effects of stimulating the fourth lumbar-nerve root and the fourth lumbar-nerve root with the first sacral-nerve root.

The results are represented in Table III.

CASE 25. R.W., stimulation of the third lumbar-nerve root. This was done on the second postoperative day. With very light stimulation, sharp pain was felt at the medial aspect of the groin. It appeared immediately and, on increasing the stimulus, it spread along a path about two inches wide down the medial side of the thigh to the medial side of the patella (Fig. 4). It disappeared on relaxing the nylon thread and reappeared as soon as the root was touched. The longitudinal spread of the pain was proportional to the degree of pressure exerted on the nerve. With slight touch, pain was felt in the groin; but, on increasing the pressure, it spread down the thigh and could be maintained at a certain point by maintaining a particular pressure. It only spread further when the pressure was increased. The spread down the thigh did not appear to be related to the length of time that the nerve was under pressure but rather to the degree of pressure exerted. Pain could be caused down the whole of the medial side of the thigh immediately by a relatively strong pull on the nylon.

CASE 26. M.C., stimulation of fourth lumar-nerve root. A band of pain about half an inch wide spread down the center of the thigh from a point one inch medial to the antero-superior spine to just above the patella (Fig. 5). It spread fairly slowly and again the pressure on the nerve root seemed to govern the distance traveled, though it could not be made to go beyond the knee. On ceasing to stimulate, pain stopped immediately. When traction was maintained for a minute, subjective numbness was experienced over a band seven

inches wide on the front of the thigh from the groin to the patella (Fig. 5). On testing objectively, loss of sensation to pin prick corresponded exactly with this area.

Case 27. C.C., stimulation of fifth lumbar-nerve root. Pain was caused along the posterolateral part of the thigh as described in previous cases but it did not radiate further. On exerting a pull for a minute and a half no sensory change of any kind was produced.

Case 28. R.R.S., stimulation of first sacral-nerve root. This caused pain exactly as described in Case 25. The longitudinal extent of the pain was proportional to the degree of pressure exerted on the root. On maintaining a continuous pressure for a minute, sensory changes were produced as depicted in Figure 6.

Case 29. D.C., stimulation of the first sacral-nerve root. Pain was produced but not along a continuous pathway. It was experienced in a series of isolated spots down the back of the thigh and lateral side of the calf, ending about one inch above the ankle (Fig. 7-A). Its downward spread was related to the pressure exerted on the root. On maintaining pressure on the root for a minute and a half, no additional sensory changes were produced. Some sensory changes were present after the operation and are shown in Figures 7-B, 7-C, and 7-D.

Case 30. E.S., stimulation of the first sacral-nerve root. Pain was caused as described in Case 29. No sensory changes were produced after maintaining a pull on the root for two minutes (Fig. 8).

Case 31. K.R., stimulation of the first sacral-nerve root. The pain distribution was exactly the same as in the other cases of first-sacral-nerve-root stimulation. After operation there was an area of objective loss of sensation to pain as shown in the diagram (Fig. 9).

Case 32. M.S., stimulation of third and fourth lumbar-nerve roots. With stimulation of the third lumbar-nerve root, pain was felt at first just below the patella and then spread up the anterolateral part of the thigh as shown in Figure 10. No sensory changes could be produced. On stimulation of the fourth lumbar-nerve root pain was felt at first over the anterolateral aspect of the upper portion of the calf and then along a path about two and a half inches wide, to three inches above the lateral malleolus, then in the lower anterolateral part of the thigh extending upwards as indicated in Figure 10. As in previous cases, the spread of the pain up or down the limb was proportional to the pressure on the root. With pressure on the root maintained for a minute a localized loss of sensation to pain on the lateral side of the knee was produced (Fig. 10). It receded and disappeared after a few seconds on releasing the pressure.

This case was of special interest in that there was a definite quadriceps weakness immediately after operation. The patient could only extend the knee to 170 degrees against gravity, and the knee reflex was absent. Muscle power was recovered, and the knee could be fully extended after eight weeks. The knee reflex, however, was absent nine weeks after operation. These complications were due to stretching the third lumbar-nerve root at operation, a note of which was made at the time.

Case 33. J.K., stimulation of fourth lumbar-nerve and first sacral-nerve roots. On stimulation of the first sacral-nerve root, pain distribution was the same as in the other cases where the first sacral-nerve root was stimulated. Stimulation of the fourth lumbar-nerve root caused pain to spread down the center of the thigh as indicated in Figure 11. It corresponded exactly with the findings in Case 26 (Fig. 5).

Case 34. J.M., stimulation of fifth lumbar and first sacral-nerve roots. On stimulation of the first sacral-nerve root, sciatica was reproduced with the characteristic distribution of pain associated with the first sacral-nerve root (Fig. 12). When the fifth lumbar-nerve root was stimulated the distribution of pain was similar to that when the first sacral-nerve root was stimulated (Fig. 12). When the first sacral-nerve root and then the fifth lumbar-nerve root were separately stimulated the patient was unable to distinguish between the two; the pain and its distribution appeared the same to him. No sensory changes could be produced by stimulation of either root.

Case 35. J.N., stimulation of the fifth lumbar-nerve root and first sacral-nerve root. Stimulation of the first sacral-nerve root caused pain distribution similar to that of previous cases (Figs. 13-A and 13-B). On maintaining pressure on the root for two minutes

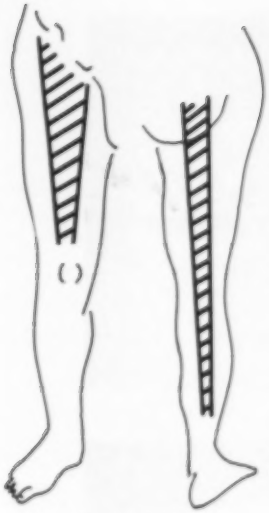

FIG. 11 FIG. 12 FIG. 13-A FIG. 13-B

Fig. 11: Case 33. Hatched lines in drawing show radiation of pain on stimulation of the fourth lumbar-nerve root.

Fig. 12: Case 34. Hatched lines in drawing show radiation of pain on stimulation of the fifth lumbar and first sacral-nerve roots. No difference in the path of pain could be detected.

Fig. 13-A: Case 35. The crossed line in this photograph follows the path of pain radiation in the right thigh on stimulation of the right fifth lumbar-nerve root, the continuous line on stimulation of the first sacral-nerve root.

Fig. 13-B: The crossed lines outline the area of pain radiation on stimulation of the right fifth lumbar-nerve root and the continuous lines on stimulation of the first sacral-nerve root. The broken line encloses the area of postoperative loss of pain sensation, unchanged by pressure on the fifth lumbar or first sacral-nerve roots. The hatched area shows loss of pain sensation after pressure on the first sacral-nerve root. No change could be produced by pressure on the fifth lumbar-nerve root.

sensory changes were produced as indicated (Fig. 13-B). With stimulation of the fifth lumbar-nerve root pain extended as shown in Figures 13-A and 13-B. A constant pull for two minutes produced no sensory change.

CASE 36. W.H., stimulation of the fifth lumbar-never root and first sacral-nerve root. The first sacral-nerve root was very sensitive, much more so than the fifth lumbar-nerve root. When the first sacral-nerve root was stimulated the distribution of pain was characteristic and tended, as in Case 35, to be more centrally placed in the calf than the pain resulting from stimulation of the fifth lumbar-nerve root (Figs. 14-A and 14-B). After maintaining pressure on the first sacral-nerve root for one and a half minutes no sensory changes were produced (Figs. 14-C and 14-D). When the fifth lumbar-nerve root was stimulated pain was produced as shown in Figures 14-A and 14-B. It will be noted that pain began somewhat more proximally in the thigh, and its path tended to be more laterally situated than that of the first sacral-nerve root. No sensory changes could be produced after two and a half minutes pressure on the fifth lumbar-nerve root.

CASE 37. K.W., stimulation of the fifth lumbar-nerve root and first sacral-nerve root. Figure 15 shows pain pathway and sensory changes when the fifth lumbar-nerve root was stimulated. When the first sacral-nerve root was stimulated the pain distribution was somewhat unusual in that it began higher in the thigh and only extended two thirds of the way down. It did not spread to the calf (Fig. 15). With prolonged pressure, no sensory changes were produced.

DISCUSSION

It was taken as reasonable to assume that a pull on the nylon thread, sufficient to bring it in contact with the nerve root, would closely simulate the irritation and pressure of a herniated disc. In no sense could it be said that the root was stretched, as the traction, if it could be called such, was no more

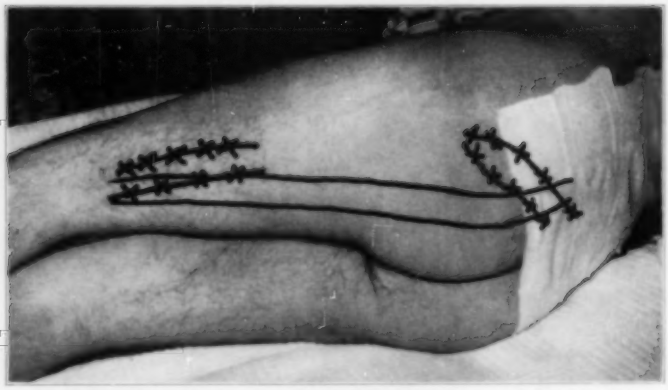

FIG. 14-A

FIG. 14-B

Figs. 14-A and 14-B: Case 36. In these photographs the areas between the crossed lines indicate the paths of pain radiation on stimulation of the left fifth lumbar-nerve root and areas between the continuous lines on stimulation of the left first sacral-nerve root.

than taking up the slack in the thread. The root was touched by the nylon rather than stretched or pulled by it. Besides, it is known that the lumbar-nerve roots have considerable play and freedom of movement [1]. It appeared unlikely, then, that stretching the nerve root was the cause of the pain experienced by the patients. The more probable cause was the touch and pressure of the thread on the anterior and lateral aspects of the nerve root—the parts which had been pressed on by the herniated discs. Removal of the discs had given complete relief from sciatica; pressure on the roots at the same places as the discs had pressed caused sciatica. The patients were virtually unaware of stimulation and movement of the dura mater. The ligamentum flavum and interspinous ligaments were insensitive. Traction on the annulus fibrosus did not cause sciatic pain. It was taken as a logical deduction that the herniated nucleus pulposus had caused sciatic pain; it seemed that the pain was caused simply by touching or pressing the roots rather than stretching them.

These findings would appear to invalidate the statement by Kelly that pressure on nerve roots is not a common primary because of sciatic pain.

Pain

When the nerve root was stimulated pain was felt at once. It was sharp

FIG. 14-C

FIG. 14-D

Figs. 14-C and 14-D: The hatched areas in these photographs show the postoperative loss of pain sensation. This extended to the areas outlined by the broken lines following pressure on the left first sacral-nerve root. No sensory changes in the leg or foot could be produced by pressure on the fifth lumbar-nerve root.

and unpleasant at first, but some degree of tolerance developed after a few stimulations. The pain was not felt so acutely. The nerve root which had been pressed upon by a disc was much more sensitive to the touch of the thread than a neighboring nerve root which was not involved in the herniation. Prolonged irritation appeared to have made the root hypersensitive. This finding may explain the reappearance of sciatica following a period of relief after the removal of a disc. After operation, pressure and irritation are removed and sciatica disappears. The nerve root, however, remains hypersensitive. In due course reactionary fibrosis occurs in the region of the root. This has an irritant effect on the sensitized root and it is exacerbated by the tethering which occurs and

prevents the root from moving freely and adapting itself to spinal and limb movements. The tethering associated with movement is analogous to pulling on the root with a nylon thread. If this is the pathological sequela of events rather than a recurrence of the herniation, it suggests a different line of approach to this problem and opens up the possibility of different methods of treatment.

The longitudinal extent of the pain appeared to be proportional to the amount of pressure exerted on the nerve root. In most of the patients, pain could be held at different levels by different pressures. The length of time the pressure was maintained did not appear to be of any significance; pain did not extend further on maintaining the same pressure for a longer period. This observation may have an important clinical application. The extent of the sciatic pain may be an index of the size of the herniation and the degree of pressure on the nerve root. If this is so, a more rational approach to treatment is suggested. Sciatic pain in the thigh alone could be confidently expected to yield to conservative treatment, while the outlook for this form of treatment in the fully developed sciatica, involving the whole extremity, would be less hopeful.

FIG. 15

Case 37. The crossed lines indicate the paths of pain radiation on stimulation of the right fifth lumbar-nerve root. Stimulation of the first sacral-nerve root produced the same path of pain in the thigh but none below the knee. The hatched lines below the knee indicate the area of loss of pain sensation after pressure on the fifth lumbar-nerve root. The hatched lines on the foot mark the area of postoperative loss of pain sensation, unchanged by pressure on the fifth lumbar or first sacral-nerve roots.

In all patients, the pain path was a relatively narrow one and, in most, no more than one and a half inches wide. Each nerve root had its own pain pathway distinct from its fellow, although, in the case of the fifth lumbar-nerve root and first sacral-nerve root, the distinction was not so clear. It would be possible, however, in a larger series of cases to construct a chart showing a fairly accurate pain path for each of the lumbar and first sacral nerves. The obvious advantages of such a chart for the localization of lesions in the lumbar spine need not be stressed. To obtain a reliable chart, however, a large number of nerves would need to be tested. This is outside the scope of the present work which in many respects must be incomplete. The ligamentum flavum and interspinous ligaments appeared to be insensitive to traction, but in the one case where the annulus fibrosus and posterior longitudinal ligament were tested, backache in the lower portion of the lumbar spine was caused. No deductions, however, were drawn from this one case, although the thought springs to mind that the annulus fibrosus may be the culprit in the causation of backache associated with a disc herniation.

The electromyographic findings were interesting in that they appear to refute the contention that muscle spasm is the mechanism whereby pain is produced when a nerve root is irritated.

Straight-Leg-Raising Test

This test was positive at a position under 30 degrees in all patients in whom sciatic pain was caused by stimulation of the fifth lumbar-nerve root and first sacral-nerve root. Positive means that the existing artificially produced pain was made worse on attempting to straighten the leg. It would seem therefore that the test can be positive before the nerve root has begun to move as it is known that the root does not begin to move until the straight leg-raising has reached a position of at least 30 degrees flexion [1]. Under our experimental conditions, it appeared that when the test was being performed the patient immediately tightly contracted the muscles of the lower extremity; the pelvis, the lumbar spine, and the lower extremity moved in one piece causing movement of the thread on the nerve root. Presumably, with a large herniation the same sequence of events occurs, and the herniation moves on the nerve root rather than the root on the herniation, giving a positive test well under an angle of 30 degrees.

Reflex, Motor, and Sensory Changes

There were no knee reflex changes produced by pressure on the nerve roots, but in the majority of those tested the ankle reflex was already absent.

Weakness of the extensor hallucis longus was found in three patients, and in one this was aggravated by pressure on the nerve root. In every patient tested, objective sensory changes could not be produced by pressure on nerve roots. In five patients, however, loss of pain sensation did occur with pressure on nerve roots (two on the fourth lumbar, one on the fifth lumbar, and two on the first sacral-nerve roots). In two patients pressure on the first sacral-nerve root increased the area of diminished pain sensation already present.

In no patients were reflex, motor, or sensory changes produced by pressure on the dura mater (Table III). These findings support the suggestions that it is pressure on the nerve root by the herniated disc which is responsible for the clinical picture in such cases of sciatica.

Clinical Significance of Experimental Findings

It has been established that the nerve root need only be touched to cause sciatica. It would also appear that if touched repeatedly or continuously, the root becomes hypersensitive.

In the treatment of sciatica, therefore, by conservative means, immobilization of the lumbar spine should be started as early as possible and should be as complete as possible. The criterion of adequate immobilization is relief from pain. Immobilization, however, can only relieve pain caused by movement of the nerve root on the disc. If, therefore, after a week or so with good immobiliztion, pain still persists, it means that the disc is still touching the root. It would seem reasonable not to continue too long with a conservative form of treatment as the nerve root may become very sensitive and continue to cause pain even after the removal of a disc. Postoperative reactionary fibrosis with a sensitized root may be sufficient to maintain an acute sciatica.

The fact that touch alone is sufficient to cause sciatica has an important bearing on operative procedure. If, at operation, no definite herniation can be seen, the suspected space should still be explored and the nucleus pulposus removed since it almost certainly is the culprit even though no gross protrusion is evident at the time. A gross protrusion is not necessary for the causation of sciatica.

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Patellectomy

(Continued from page 1284)

DISCUSSION

Dr. Ralph Soto-Hall, San Francisco, California: Patellectomy confronts the surgeon with many technical problems which if they are not solved lead to failure. Lack of understanding of these problems has led many surgeons to condemn the operation. The procedure must vary with the disease being treated, and one must recognize that the excision of the patella is only incidental to the important part of the operation which is the proper repair and handling of the quadriceps tendon.

Patellectomy produces a relative increase in the length and width of the quadriceps; therefore, reefing must be carried out in order to restore proper tendon tension. Lengthening is in the long axis of the leg; there is also lengthening in the tranverse axis. In the latter direction the vastus medialis is weakened by lengthening its contracting range. It is my opinion that one of the causes of failure often reported—loss of full extension after patellectomy—results from neglecting to take up properly this transverse slack.

I had the opportunity to do a V-plasty on a patient with a neglected case of non-union. I found this operation to be ideal for restoring the proper tendon tension in both directions. This operation, however, I believe, should be limited to patients with severely comminuted fractures or to those in whom the quadriceps tendon is intrinsically weak.

One condition for which I believe it is illogical to do a simple patellectomy is chronic or recurrent dislocation of the patella. A simple patellectomy does not correct the pathomechanics of the lesion and, therefore, a continuance of the slipping or dislocation of the tendon results. For that reason Dr. West and I suggested a procedure by which the tendon is shifted medially and is reefed lengthwise to overcome the lengthening. The vastus medialis is then overlapped in a V-shaped tongue and is brought over the defect created by the excision of the patella. This operation reinforces the area of the defect and restores proper tension of the vastus medialis.

I would like to ask a question of the authors: The quadriceps tendon is not a single solid structure. It is subdivided into three parts, that is—the rectus, the part of the two vasti, and the intermedius. I wonder whether it would not be satisfactory to bring down the rectus alone and overlap the area making a U-shaped operation? This would certainly avoid adhesions and tying down the two inferior layers of the quadriceps.

Dr. Shorbe (closing): As far as the U-plasty as against the V-plasty, I think either would be satisfactory. The V-plasty tends to pull the quadriceps expansion together a little better, it is also easier to close at its upper end. I do believe if the rectus femoris part of the quadriceps tendon separates easily, it would be ideal to use.

Traumatic Anterior Dislocation of the Hip in Children

BY LYNN O. LITTON, M.D., AND CHARLES WORKMAN, M.D., KANSAS CITY, KANSAS

Most authors discussing traumatic anterior dislocation of the hip in children emphasize the rarity of its occurrence[2, 3]. Choyce, in reviewing the world literature prior to 1924, found ten anterior dislocations of the hip in fifty-nine traumatic dislocations of the hip in children. Additional cases have since been reported by Haines, Thompson and Epstein, Banks, Glynn, Niloff and Petrie, and Hamada. These cases are summarized in Table I. An additional case is reported here with a review of the literature since 1924.

FIG. 1

R. C., a five-year-old white male, was seen in the Emergency Room of the University of Kansas Medical Center on August 26, 1954, about thirty minutes after having been run over by a car. The details at the injury are not known, but the car was seen passing over the boy's left thigh.

Examination revealed a lethargic patient whose breathing was labored. There were petechial hemorrhages on the face, neck, scalp, left axilla, and both conjunctiva. The face was cyanotic and slightly oedematous. The left hip was flexed, abducted, and externally rotated. The entire left thigh was swollen, and there were several abraded areas on the leg (Fig. 1). The femoral head was palpable anteriorly in the subinguinal area. Motion of the left hip was very painful. The blood pressure was 100 systolic and 60 diastolic, pulse 100, and respiratory rate 28. Examination of the urine and blood were normal. Roentgenograms showed an anterior dislocation of the left hip (Figs. 2 and 3).

It was thought that the child had sustained a crushing injury of the chest since the

FIG. 2

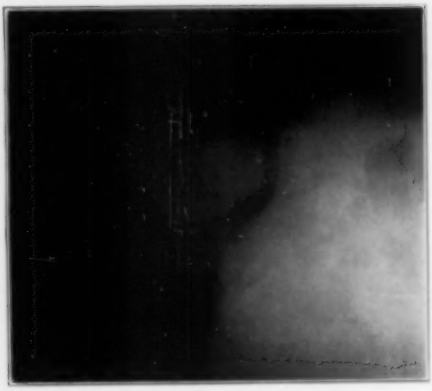

FIG. 3

FIG. 4

petechial hemorrhages were confined to the face and upper extremities. His condition appeared critical, and he was placed in an oxygen tent. Other supportive measures were started. The left lower extremity was placed in Buck's traction. In spite of a clear airway, he remained cyanotic with marked respiratory difficulty. Marked lethargy, drowsiness, disorientation, and confusion persisted for several days, indicating cerebral damage.

After eight days, his general condition had improved sufficiently for him to tolerate anaesthesia. A closed reduction was carried out on September 3, 1954, in which the Bigelow maneuver was used. Considerable force was necessary because of the delay. A simple plaster hip spica was applied and roentgenograms were made. These were of poor quality but they were interpreted as showing reduction of the hip. The child was discharged on September 9, 1954.

The plaster was removed on October 6, 1954, and roentgenograms were made. These showed a posterior subluxation. Re-examination of the original roentgenograms made after manipulation then disclosed that reduction probably had never been obtained. It was thought that during manipulation the hip had been internally rotated so far that the femoral head was pushed posteriorly past the acetabulum. An open reduction of the subluxation of the hip was done on October 7, 1954. The ligamentum teres had been avulsed and fatty tissue filled the acetabulum. The ligamentum teres together with other soft tissue lying in the acetabulum was excised and the subluxation reduced. The patient was placed in a single hip spica cast with the

TABLE I

A SUMMARY OF CASES OF TRAUMATIC ANTERIOR DISLOCATION OF THE HIP IN CHILDREN REPORTED SINCE 1924

Author	Age	Sex	Side	Type	Treatment	Result	Comments
Banks	12	M	Left	Obturator	Closed reduction	Good	Aseptic necrosis developed but head re-formed and functional result at 6 yrs. was good
Glynn	7	F	Right	Obturator	Closed reduction	Good	
Haines	6	M	Left	Unspecified	Closed reduction	Good	
Hamada	9	F	Unknown	Unspecified	Osteotomy	Good	Injury 5 mos. before treatment
Hamada	12	M	Unknown	Unspecified	Osteotomy	Good	Injury 1 yr. before treatment
Niloff and Petrie	14	M	Left	Unspecified	Closed reduction	Good	
Thompson and Epstein				Unspecified	Closed reduction	Good	

left lower extremity in abduction and internal rotation. The cast was removed in two months and an ischial weight-bearing brace was worn for four additional months. Roentgenograms showed no suggestion of aseptic necrosis three years later (Figs. 4 and 5). There is a slight irregularity of the head. Slight limitation of rotation, which was improving, remained. The gait was normal in running and walking.

The mechanism of the injury producing an anterior dislocation of the hip has been discussed by several authors. According to Compere and Banks, anterior dislocation follows severe blows to the leg with the extremity in abduction. Astley Cooper stated the cause as usually due to stepping unexpectedly into a hole with

FIG. 5

the body bent backwards, forcing the head of the femur anteriorly. The mechanism of injury in this case cannot definitely be stated but it is thought to be similar to that reported by Niloff and Petrie. In this case, the leg was forced into extreme external rotation with the extremity in abduction.

Treatment of the dislocation should be immediate and based upon an evaluation of the type of dislocation and general condition of the patient. Most authors report excellent results following closed reductions by either the Bigelow or Allis maneuver[6, 8, 11]. Occasionally an open reduction is necessary[10]. Open reduction in this case was the result of failure to reduce this dislocation by closed methods.

Many complications occur in the treatment of anterior dislocations of the hip besides posterior subluxation. Infection and fracture of the shaft of the femur occur[3]. There has been one case of aseptic necrosis reported following traumatic anterior dislocation of the hip in a child[1]. This apparent rarity we believe to be related to the fact that the larger vessels supplying blood to the femoral head are through the posterior capsule[9].

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Paget's Disease of the Patella

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For fifteen years, a patient with a peculiar lesion of the patella was followed on the Orthopaedic Service of the Stanford University Hospital. Patellectomy was eventually carried out. The roentgenographic and pathological diagnosis was Paget's disease. Only the patella was involved.

M. E., a white woman, fifty-seven years old, was first seen on March 4, 1943, at Stanford Hospital, complaining of a painful, swollen left knee of four months' duration. In November 1942, while riding on a bus, she lurched forward, lightly striking her left knee on a suitcase. She immediately felt a severe, sharp pain which, for five days, prevented her from walking. She had

FIG. 1

FIG. 2

Fig. 1: Roentgenograms of left knee on original examination at Stanford Hospital in 1943.
Fig. 2: Roentgenograms of left knee prior to patellectomy in 1956.

no previous history of injury or discomfort of this knee.

She consulted her own physician, who made the diagnosis of Paget's disease of the patella, without evidence of fracture, and treated her conservatively. The symptoms persisted, with only moderate relief, and she was therefore referred to Stanford Hospital.

Examination on March 4, 1943, revealed a thick, irregular, tender left patella. The overlying skin was warm. The knee joint was normal. A roentgenogram of the knee confirmed the previous diagnosis (Fig. 1).

Treatment by immobilization in a cylinder cast relieved her symptoms within six weeks, and she remained in good health for twelve years. In May 1955, she twisted her left knee and had a recurrence of mild pain in this region. Symptoms increased gradually during the following eight months, at which time she returned to Stanford Hospital.

Examination showed warmth, exquisite tenderness, and further irregular enlargement of the patella.

Roentgenograms demonstrated progress of the disease process (Fig. 2). Because of the severe symptoms, patellectomy was carried out on February 20, 1956, thirteen and a half years after the original diagnosis. No other pathological process was noted in the knee joint during the operation. The histological diagnosis was Paget's disease involving the entire bone (Figs. 3 and 4).

The patient had an uneventful postoperative course. When she was last seen twenty months

FIG. 3

Roentgenograms of specimen of patella after excision.

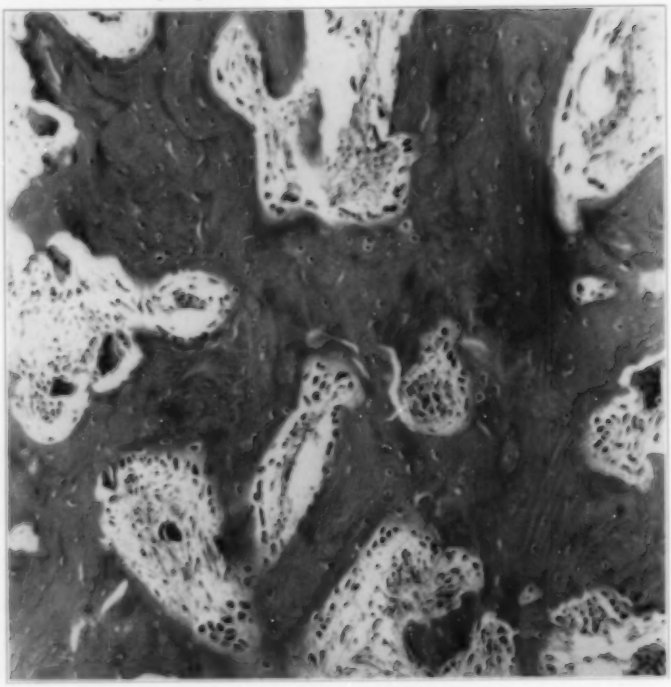

FIG. 4

Photomicrograph shows the pathognomonic mosaic trabecular structure and vascular, fibrotic marrow spaces (hematoxylin and eosin).

later, the functional and cosmetic results were excellent. She had a full range of painless motion of the knee.

A skeletal survey again showed no evidence of other bone involvement.

DISCUSSION

While this is thought to be the first reported instance of the condition localized to the patella, attention should be brought to a case report in an article entitled "Post-traumatic Osteosclerosis of the Patella of the Type of Osteitis Deformans of Paget" [4]. In this article, von Hunziker presented a local lesion of the patella pathologically identical with that in the present case. However, this case was diagnosed as osteosclerosis rather than true Paget's disease because of a history of repeated trauma.

Since neither trauma nor any other cause has been reported to have produced such lesions in bones, including the sesmoid bones, Hunziker's case is in all probability monostotic Paget's disease.

While there are some who do not feel monostotic Paget's disease is a definite entity [4], many pathologists, orthopaedists, and roentgenologists think it does occur [1, 2, 3]. Osteitis deformans is rarely reported in the patella even in its polyostotic form. Dickenson reported only four instances in 365 cases. There are reports of involvement of all other bones in the polyostotic disease—some as rarely as the patella. It seems probable that if the monostotic form is in reality the same disease as the polyostotic form only locally expressed, then monostotic Paget's disease might occur in any bone or sesmoid bone of the body.

ADDENDUM: Our attention has been brought to A. D., a woman, fifty-four years old, who has been followed for ten years in another hospital for a lesion localized in the left patella. Patellectomy was done eight years ago and although the pathological report was identical with that in the case presented the specimen and slides have since been lost. Results from surgery were excellent. No other lesion has been found. This case apparently represents monostotic Paget's disease of the patella but we are unable to prove it to our own satisfaction.

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Median-Nerve Compression at the Wrist

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A taxicab driver, J. B., thirty-three years old, had his left forearm and wrist crushed in an automobile accident; the pain and discomfort disappeared after a few days. Seven months

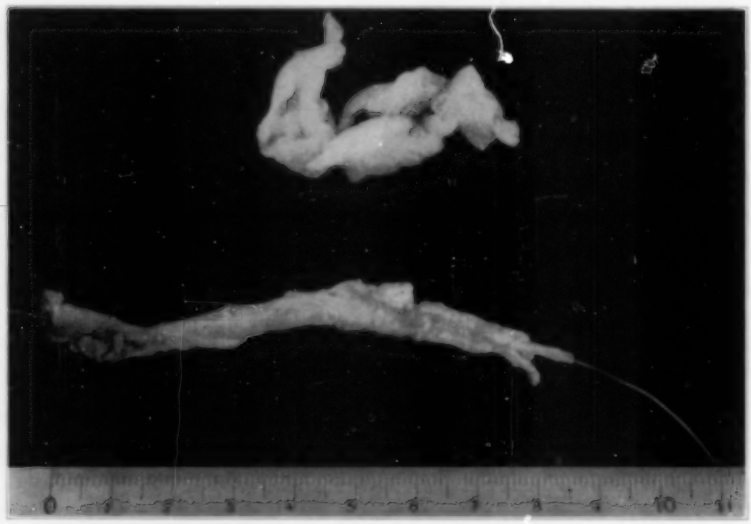

FIG. 1

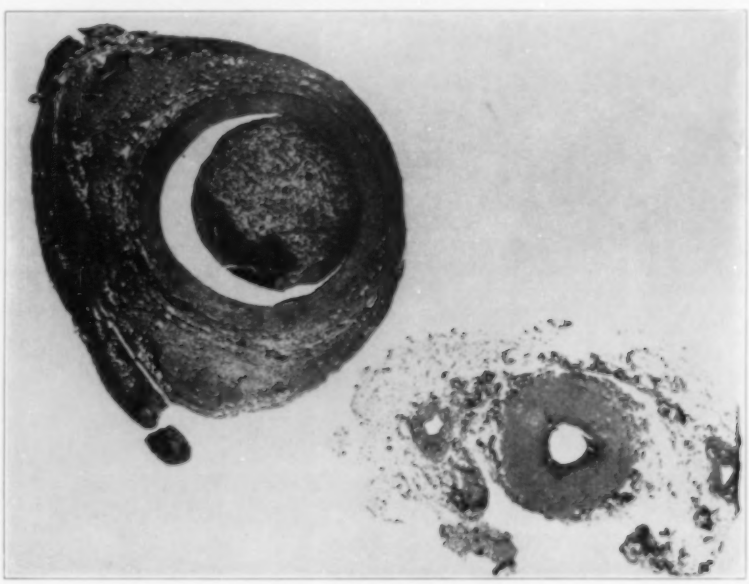

FIG. 2

later, in July 1956, some tingling at the tip of the thumb appeared, progressing to pain which spread to the thenar region and to the index, long, and ring fingers. The patient was unable to sleep. At the first hospital where the patient was treated, the wrist was immobilized in plaster. The pain became even more severe and after two weeks the plaster had to be discarded. Some relief was obtained by laying the flexed wrist across the trunk.

The patient was seen by the authors on December 16, 1956. Physical examination revealed that the palmar aspect of the wrist was of normal color, with some swelling present. There were trophic changes in the fingernails of the thumb, index finger, and long finger without muscle wasting. The patient had burning pain throughout the distribution of the median nerve at the slightest touch to the palmar aspect of the wrist. High median-nerve compression (cervical spondylarthritis, disc protrusion, cervical rib, scalenus and pectoralis minor syndromes) was ruled out, as well as local osseous causes (fracture or dislocation). The diagnosis was compression of the median nerve in the carpal tunnel and what was subsequently found was not suspected.

The patient was operated upon on December 20, 1956. After division of the volar carpal ligament and opening of the carpal tunnel, it was found that the median nerve was surrounded by dense fibrous tissue, extending toward the forearm.

The incision was enlarged proximally and the median nerve carefully dissected; it was enlarged two centimeters above the wrist. A fibrous mass surrounded the nerve and a large vessel was running in the center of the forearm. We were puzzled by the presence of this vessel that we were not able to identify. As the vessel was not pulsating and crossed the mass of fibrous tissue causing the compression, it was ligated at both extremities and a specimen nine centimeters long was resected.

Pathological examination revealed, macroscopically, a thrombosed blood vessel (Fig. 1). Microscopically, a cross section of the artery showed the process of organizing thrombosis (Fig. 2).

The postoperative diagnosis was median-nerve compression at the carpal tunnel by a persisting thrombosed median artery. The patient had no more referred pain after operation and he returned to his work as a taxicab driver.

In making the diagnosis, before thinking of the possibility of compression of the median nerve by a thrombosed artery, the usual causes of high compression of the nerve and local causes had to be ruled out. The diagnosis was made only at operation, after excision of a persisting thrombosed median artery, surrounded by dense fibrous tissue.

Proceedings

JOINT MEETING OF THE ORTHOPAEDIC ASSOCIATIONS OF THE ENGLISH-SPEAKING WORLD

Infantile Structural Scoliosis. Mr. J. I. P. James [1] and Mr. G. C. Lloyd-Roberts [2] first reported thirty-three cases of infantile structural scoliosis in 1951. Since then 191 infants were seen with structural scoliosis of unknown etiology and with onset before the age of three years. Of the 191 infants, 135 had structural curves which were progressive in nature. Fifty-six of the patients, however, had curves which disappeared completely during the first few years of life. Characteristically, the resolving infantile structural curves usually are not present at birth but appear during the first year of life; the angle is usually between 10 and 30 degrees, and is a left thoracic curve. It is usually a long curve without any compensatory curve. The progressive infantile structural curves are sometimes shorter, almost always have secondary compensatory curves, may be double curves, and may be usually more than 35 degrees. However, it was pointed out that no absolute distinction is known, and there is much to suggest that initially the two types of curves are identical. The prognosis on the infantile structural progressive curve is very poor. It would appear, from studies made by Mr. James and Mr. Lloyd-Roberts, that the inevitable result is the development of a curve of more than 70 degrees and a great majority of children, if left alone, would have curves of more than 100 degrees. It is recommended that the children be supported with a Milwaukee type of scoliosis brace until they are ten, and then operative correction and fusion be performed. The majority of patients will require this therapy. The etiology of this condition has not been wholly ascertained, but it is not related to congenital anomalies or poliomyelitis. Infantile structural scoliosis occurs most often in males and is a left dorsal curve of more than 35 degrees. Associated with this curve there are rotation and secondary compensatory curves. The curve is usually short, as compared with the long curve that is present in the resolving type.

Congenital Pseudarthrosis of the Tibia. Dr. H. B. Boyd [3] and Dr. F. P. Sage [4] reported their experience with fifteen patients operated on for congenital pseudarthrosis of the tibia. Seven of the fifteen patients had reached skeletal maturity and thus were included in an end-result evaluation. The other eight patients were still in the actively growing period and were not considered eligible for final evaluation by the authors, since refracture is common during the growing period.

All of the seven patients who had reached skeletal maturity had repeated reconstructive operations. The result of one of the patients was classified as a failure because a below-the-knee amputation was necessary. Three patients had moderately successful results, although two needed braces and one needed a shoe elevation. The results of three patients were considered successful; they had solid bone union and needed no additional support. Primary therapy in these patients consisted in the use of dual onlay bone grafts obtained from the mother's tibia.

In two cases treated more recently the authors employed an intramedullary rod after the technique of Charnley and Sofield. They advocated this technique as a possible means of preventing refracture which occurs subsequent to the thinning of the shaft of the tibia during the active growth period.

The authors recommended that surgery on congenital pseudarthrosis be performed as soon as the operation can be done safely. In addition to presenting fifteen cases, the authors also summarized the available literature on the subject and reviewed the cases previously reported.

The authors believe that there are two distinct types of congenital pseudarthrosis of the tibia. In the first, a cystic defect with or without fracture is present. The material removed from the cystic defect resembles that of fibrous dysplasia. The second type shows sclerosis and tapering of the bone ends, probably due to a constricting band of fibrous tissue. In the latter type, union is much more difficult to obtain than in the cystic type with fracture.

In the cystic defects without fracture, they recommended curettage of the cystic defects and packing with bone chips. The authors thought that pseudarthrosis may be prevented by this technique.

Regardless of the procedure which is performed, all patients must be observed throughout the period of growth; and the tibia should be protected until one of relatively normal size

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develops. It may be necessary to apply additional bone subperiosteally to reinforce the tibia during the growth period.

In patients with extreme deformity, amputation may be performed if it is apparent that a prosthesis will provide a more functional extremity than that obtained by reconstructive surgery.

The authors evaluated the various techniques which have been applied to the solution of this very difficult problem. They concluded that multiple procedures are frequently necessary to obtain satisfactory union.

Congenital Absence of the Fibula. Dr. C. A. Laurin [5] and Dr. A. W. Farmer [6] presented a review of congenital absence of the fibula in thirty-two limbs (twenty-four patients). The material had been obtained from the Hospital for Sick Children in Toronto between 1931 and 1957. The term, congenital absence of the fibula, although widely used was objected to because it was considered misleading. The authors suggested that this condition be called lower extremity dysplasia associated with the absence of the fibula. The absence of the fibula is merely a striking roentgenographic feature and the hallmark of a congenital abnormality which is actually dysplasia of the entire limb. There is no sex predominance. Lesions of the right side are slightly more frequent than of the left; one-third of the patients have distal malformations. The absence of the fibula may be complete or incomplete. However, the pathological changes are never limited to the fibula but involve, in order of severity, the tibia, the foot, and the femur. The tibia is constantly affected. It is invariably shortened and is usually bowed anteriorly and laterally. The foot is always in valgus position and equinus deformity.

Dr. Laurin and Dr. Farmer felt that there is no standard treatment for congenital absence of the fibula and the problem is not absent bone but a dysplastic limb. The three common complaints are foot deformity, tibial bowing, and length discrepancy. The foot deformity is usually mild. The tibial bowing, *per se*, rarely presents any difficulty and accounts for very little shortening. The authors differed with the views of Dr. T. Campbell Thompson in that they felt that removal of the fibular anlage in all patients is not necessary. Spontaneous improvement of the anterior bow will occasionally take place. Tibial bowing is always maximal at birth and is not aggravated by growth. It may occasionally regress. Bowing never develops in a straight tibia. If the deformity is mild, no harm will come from delayed surgery. However, should the bowing be severe, a tibial osteotomy, excision of the fibular anlage, and a lengthening of the tendo achillis is necessary. The leg-length discrepancy is handled by one of the conventional methods. Amputation is by far the most practical procedure and is employed if the shortening exceeds five inches. Leg-length equalization is considered in shortening of lesser degree. The foot deformity is also a factor in the employment of a prosthesis. The operation of choice is the amputation of Symes which is modified by applying the calcaneus to the lower end of the tibia. The earlier the amputation is done, the better.

Paraplegia in Children. Dr. Paul L. Norton [7] and Dr. John J. Foley [8] pointed out the possibilities and the results of better rehabilitation in paraplegic children. They reviewed sixty-five patients with gross lesions of the spinal cord. Forty-eight had congenital spina bifida, and seventeen had acquired paraplegia. The neural-arch defects reached as high as the sixth thoracic vertebra in one instance although the majority of the defects had their upper limit at the third lumbar vertebra. The average stay in the Hospital School was six years for these patients. At the time of the report twenty-four of the patients with congenital paraplegia were in the hospital and twenty-four had been discharged. Forty-one of the forty-eight patients are still alive; their average age is fifteen and one half years. There are six patients whose ages are between twenty and thirty years. The authors concluded that congenitally paraplegic children who survive their early years have a better chance for reaching adult life than is generally recognized. The authors felt that the rehabilitation program of these patients should be geared toward teaching them a gainful occupation.

Twenty-six of the forty-eight patients had good balance, while six had poor to fair balance. Nine at the time of the report were non-ambulatory, four were in training, and three had no serious gait problems.

The authors reported that 144 surgical procedures were done on this group of patients. There were three spine fusions, fifteen stabilizing operations of the hip (twenty-eight hips were dislocated, nineteen subluxated); twenty-two procedures for release of flexion and adduction contracture, three erector spinae transplantations, eleven operations on the femora, including four open reductions for fractures (which were rare). Bilateral dislocations of the hip were left uncorrected. For flexion contracture of the knee, eleven hamstring-lengthening procedures and three Eggers' hamstring transplantations were performed. There were twenty-nine stabilizing procedures of the foot and ankle, and forty soft-tissue operations of the foot.

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Seventeen children with paraplegia, acquired at birth or later, were also studied. Sixteen of these patients survived with ages ranging from seven to thirty years. The average survival from the onset of paraplegia until this time is fourteen years in the nine oldest patients. Thirty-three operations were done on this group, including one spine operation, sixteen hip procedures, one femoral osteotomy, and eleven operations of the knee, foot, and ankle.

The associated rehabilitation program in urology, nursing care, general surgery, and neurosurgery was discussed by the authors along with the general program in rehabilitation including formal education and vocational training. The authors stressed particularly the importance of education. They felt that anything less than high school education or complete vocational training would generally leave the patient unemployable. Driver-training using hand controls is a tremendous asset.

The authors then analyzed the present status of the patients. It is interesting that in the group between nineteen and thirty years, six patients were capable of total self-care and were self-supporting. Four others could care for themselves but were only partially self-supporting; one was a senior in college. Three others are able to care for themselves completely but are unemployable; two patients are in institutions. Three of the patients in this group are employed in the electronics industry as specialists; one is an artist, and two are office workers. Seven of these patients operate their own cars by using hand controls.

The authors felt that their report showed the practical application of the rehabilitation of paraplegic children. They also felt that the orthopaedic surgeon should assume leadership of the team that is necessary for success.

Epiphyseal Stapling. Dr. Walter P. Blount [9] said that since his initial publication on epiphyseal stapling nine years ago the design has been improved by casting the staples. He has not modified his technique. In the distal portion of the femur staples are fitted so that their prongs parallel the epiphyseal plate. Many of the complications were caused by bending or extrusion of the staples and faulty placement. Staples were not used in patients under eight years of age. The author reported excellent results in the correction of limb-length inequality following poliomyelitis and in knock-knee deformity. The removal of staples up to four years following their insertion was followed by essentially normal growth at the epiphyseal plate until slightly premature closure of the plate was noted.

Congenital Muscular Torticollis. Dr. George G. Garceau [10] and Dr. W. L. Franklin [11] reported on their observations of thirty-two patients with congenital muscular torticollis. Ten patients were not operated on, twenty-two were treated by open surgery. The indications for operation were progression in deformity and increase in size of the tumor. All twenty-two were operated on before the age of one year; one at eighteen days. Ten patients were followed for five to ten years, five for two years, and six for one year. Five patients who have muscle fibers which function had early surgery.

The tumor consisted of an abundance of fibrous tissue which was white in appearance without apparent blood supply. The fibrous tissue invaded the surrounding muscle. Both the fibrous tissue and muscle were found in various stages of degeneration, but no evidence of reaction to trauma was observed.

In the group not operated on the tumor disappeared; the longest persistence was four months. Eight of these patients developed the associated deformities of torticollis.

While two patients reputedly had, respectively, a father and an uncle with neck deformity, heredity or associated congenital deformity did not appear pertinent.

Factors Which Predispose to Osteo-arthritis. Dr. Leon Sokoloff [12] summarized a number of studies being conducted at the National Institute of Arthritis and Metabolic Diseases examining the possibility that constitutional or systemic factors contribute to the vulnerability of joints to osteo-arthritic erosion. Osteo-arthritis simulating human degenerative joint disease occurs with frequency in certain small laboratory animals. In a series of studies performed in collaboration with Dr. Emanuel Silverstein, Dr. George E. Jay, Jr., and Dr. Olaf Mickelsen, it was shown that the occurrence and severity of the joint disease is greatly influenced by genetic, species, and sex factors. Obesity-producing diets have resulted in some increase in osteo-arthritis in certain groups of laboratory animals but not in others. Among the factors studied that have failed to be correlated directly with osteo-arthritis are rates of epiphyseal development (skeletal aging); thyroid function (extraction of radioiodide following blocking with tapazole, thyroid weight, or average nuclear height); posture; and physical activity of the animals. Preliminary studies by the Clinical Investigations Branch have demonstrated the importance of hereditary factors and physique in certain types of osteo-arthritis.

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Hemiarthroplasty of the Knee Using a Space Occupying Prosthesis for Painful Varus and Valgus Deformities. DR. D. L. MACINTOSH [13] said that in treating painful varus or valgus deformity of the knee joint due to degenerative arthritis or deforming fracture of the joint, he has performed an operation which he calls hemiarthroplasty on thirteen patients. An acrylic tibial plateau prosthesis is inserted into the affected side to correct deformity, restore stability, and relieve pain.

Through a parapatellar incision the deformed plateau is resected by a vertical cut just to the side of the tibial spines and a horizontal cut parallel to the proper plane of articulation removing as little bone as possible; it is replaced by a plateau prosthesis to restore a smooth surface and height to take up the slack of relaxed ligaments. The prosthesis, with a shallow concavity of joint surface, is slid, like a drawer, well back into the osteotomy surface and requires no other fixation. It is planned that in the future the prostheses will be metal rather than acrylic.

Of the thirteen patients whose knees were operated on, the first in 1954, eight have been followed for at least a year. Nine knees were treated for degenerative arthritis, and four for fracture deformity. In eight patients the results were considered good with wide ranges of motion—90 degrees or more in seven of these—good stability, very little discomfort, the ability to climb stairs naturally in many, and generally excellent functional capacity. Two were considered fair, and three were failures: one because of probable fracture of the prosthesis, one because of infection, and one because of pain.

Mold Arthroplasty of the Knee. DR. OTTO E. AUFRANC [14] and DR. WILLIAM N. JONES [15] described the results of treatment of eighteen severely diseased knees by Vitallium mold arthroplasty in fourteen patients. The first arthroplasty of this series was performed by the late Dr. M. N. Smith-Petersen in 1942 and a standard procedure is now beginning to evolve. The authors preferred a transverse incision across the patella whereby the posterior two thirds of this bone was excised. Three different types of knee molds were used. The one preferred was somewhat the shape of an anchor. The cross arms were hollowed to fit the reconstructed femoral condyles while the stem was driven into the medullary canal of the femur. The authors thought that postoperative adhesive traction was of definite value.

Arthroplasty was performed for rheumatoid arthritis or old sepsis of the joint and, in one patient, for recurrent giant-cell tumor. In the latter case the lateral femoral condyle was excised. Knee fusion, after removal of the mold, was performed in three patients. Of the other patients, the authors judged three as good results, five fair, and three poor.

The authors felt that there had been sufficiently good results to make them optimistic about the further development of this type of arthroplasty in carefully selected patients.

Attrition Ruptures of Tendons in the Rheumatoid Hand. MR. O. J. VAUGHAN-JACKSON [16], in 1946, had two patients, both males, who had lost the power to extend the little and ring fingers at the metacarpophalangeal joints. In each patient, the condition had occurred suddenly without injury. A full report was published in the August 1948 issue of The Journal.

In 1954, a woman, fifty-four years old, suffering from rheumatoid arthritis was examined by the author. She had had a history of sudden, painless loss of extension of the little finger followed in a week or two by the same phenomenon affecting the ring finger. At operation, rupture of the extensor tendons was found at the wrist with a defect in the lining of the tendon compartment as the tendons passed over the distal portion of the ulna. There was a rough spicule of bone at the tip of the ulna emerging directly under the tendons. The author repaired the tendons with free tendon grafts after removal of the distal portion of the ulna. Since then, he has treated twenty-three patients with attrition ruptures of the extensor tendon group and seven, of the flexor tendon group. All but two patients had rheumatoid arthritis. Mr. Vaughan-Jackson felt that the condition is not widely recognized because patients with rheumatoid arthritis and surgeons both have been preoccupied with articular manifestations of the disease.

The author recommended that these hands be examined with renewed care and a fresh outlook.

Surgical Treatment of Rheumatoid Deformities of the Hand. DR. DANIEL C. RIORDAN [17] and DR. S. BENJAMIN FOWLER [18] stated that careful examination of hands deformed as a result of chronic multiple rheumatoid arthritis demonstrates that flexed and ulnar-deviated metacarpophalangeal joints are due to subluxation of extensor tendons from the normal position overlying the metacarpal heads to the ulnar side of the metacarpal head, so that the tendons lie in the interval between the knuckles. The hyperextended proximal interphalangeal joint

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deformities are due to contractures of the intrinsic muscles, in addition to the influence of the subluxated extensor tendons. Cosmetic improvement by operation is possible in most stages of arthritis and in almost every type of deformity. Functional rehabilitation is increasingly difficult as bone atrophy and the deforming process continue. The authors demonstrated with a motion-picture film taken at operation how they exposed the extensor tendons of the four fingers by a transverse incision over the metacarpal heads. The tight, oblique fibers of the tendon of intrinsic muscle were divided, which relieved the proximal interphalangeal joints of hyperextension. The joint itself was opened in each instance and synovectomy done. The metacarpal head was then partially excised in an oblique fashion so that the contracted, ulnar-deviated fingers could be placed in proper alignment with the metacarpals. The subsequent ulnar deviation of the fingers was blocked by the shape of the transversely cut metacarpal head. A Kirschner wire, placed through the intramedullary cavities of the phalanges and the metacarpal holds the finger in its proper anatomical position during healing. The extensor tendons are then transplanted to the normal location on the dorsum of the metacarpal heads, and maintained in proper position by reconstructing the transverse fibers of the extensor mechanism.

The authors stated that these wounds healed rapidly and produced good, cosmetically acceptable, hands with improved function. The function, of course, was never again entirely normal. They attributed the loss of some function to the flexor tendons being caught within their flexor tunnels by the rheumatoid process, and stated that, in some instances, an operation on the flexor tendons might be necessary as well.

Rehabilitation of the Hand in Rheumatoid Arthritis. Dr. John G. Kuhns[19] reported that 20 per cent of patients with rheumatoid arthritis develop functional disabilities of the hand. There are three types of deformities: flexed wrist with hyperextended metacarpophalangeal joints and flexed interphalangeal joints; hyperextended proximal interphalangeal joints with ankylosis; and ulnar deviation at the metacarpophalangeal joint with flexed fingers. The author pointed out that the early changes seen in rheumatoid arthritis are swelling of the interphalangeal and wrist joints with synovial thickening and pain on motion. Muscle spasm appears later and gradually contractures and ankylosis of joints develop.

If the patient is seen early in the course of the disease, rehabilitation can be started immediately. In the acute, painful phase, the treatment consists of plaster immobilization in the position of function until inflammation subsides. After pain subsides, motion is started and a splint is applied in the functional position. At the same time the general therapy of rheumatoid arthritis should be continued. Occupational therapy is used in the later stages.

If seen when deformity is already present, the deformities should be corrected, if possible, by the application of a plaster cast followed by long periods of physical therapy. The author stated that he gets better results with conservative treatment than with surgery. He said that he occasionally recommends manipulation under anaesthesia followed by splinting and then by physical therapy and heat. He may repeat the manipulation under anaesthesia if an optimum result is not obtained.

The more severe deformities may be treated by surgery. He feels that good cosmetic results are easy to obtain, but that the amount of function restored is limited. Exacerbation of rheumatoid arthritis will cause recurrence of deformities. He recommended that surgery be done only when the patient is in an inactive state, when there is neither pain nor swelling present, and when the erythrocyte sedimentation rate is normal. Shoulder and elbow deformities should be corrected prior to correcting hand deformities. If surgery must be done, physical therapy should always precede.

Dr. Kuhns recommended fusion of the wrist for a flexed fixed deformity and advised bone-grafting since the quality of the bone is usually poor. He has tried immobilization of the wrist in good position with Kirschner wires without obtaining fusion; however, he found that the wires work loose. The author has done capsulotomies at the metacarpophalangeal joint but said that he has had poor results. Capsulotomy at the interphalangeal joints gives a more useful range of motion. In performing capsulotomy on the flexed interphalangeal joints, he incises the volar capsule through 180 degrees sparing the tendon and the collateral ligament. He has also done this for extension deformities of the interphalangeal joints. This procedure is followed by elastic traction. For severely deformed interphalangeal joints he prefers fusion in a position of 20 to 30 degrees of flexion using Kirschner wires for immobilization.

On metacarpophalangeal joints with ulnar deviation he has done joint resection removing one-quarter inch of the bone of the metacarpal head and the base of the proximal phalanx. He has not used any interposition material in this joint resection and reports no ankylosis following the procedure. The displaced extensor tendon is fixed to the radial side.

On the flexed adducted thumb he does capsulotomy at the metacarpophalangeal joint. If the metacarpophalangeal joint is damaged, fusion of the joint is done in 20 degrees of abduction, 40 degrees of medial rotation, and slight flexion.

Other conditions such as snapping-tendon and Dupuytren's contracture are treated sur-

19. 372 Marlborough Street, Boston, Massachusetts.

gically when found in the rheumatoid hand. Snapping-tendon is treated by release of the tendon sheath and Dupuytren's contracture, by fasciotomy of the contracted bands.

Rheumatoid granulations are treated differently depending upon the severity. In patients treated early in the course of the disease, rest is recommended, sometimes followed by injections of hydrocortisone if relief is not obtained by heat and rest. Larger granulations are excised surgically. Ruptured tendons are treated by grafts or are occasionally replaced by tendon transfers. Dr. Kuhns reported that some grafts and transfers tend to degenerate and may later rupture.

Spinal Osteotomy. Mr. W. Alexander Law [20] reported on over one hundred cases of spinal osteotomy; eighty of these were reviewed for this paper. Of the eighty, seventy-eight patients had ankylosing spondylitis; and in two other patients, the nature of the trouble was rheumatoid arthritis. Only six of the group were female; all were adults.

The purpose of osteotomy is: (1) To enable the patient to stand erect; (2) To improve respiratory function and diaphragmatic action; (3) To relieve visceral pressure; and (4) To make possible abdominal operation, if necessary.

Details of the operation correspond closely with those outlined by Dr. Smith-Petersen in his original article. The level chosen is preferably between the second and third lumbar vertebrae. A higher level promotes a greater chance of paralytic ileus. Osteotomies in the oblique plane are made in the region of the articular facets. These obliquely cut surfaces oppose on extension of the spine, closing the defect created by the osteotomies, with final impingement of spinous processes. This gives good stability. Occasionally it may be necessary to precede osteotomy of the spine by arthroplasty of the hip. Following spinal osteotomy, a plaster jacket is used, preferably including one hip. The average gain was 25 to 45 degrees of correction, although in one instance, with osteotomy at the fourth lumbar vertebra, 90 degrees of correction was obtained without any serious sequela.

In the cervical region the interval chosen for surgery was between the fourth and fifth cervical vertebrae. The number of patients operated upon in this region was two. The osteotomies are placed more horizontally and correspond with the direction of passage of the nerve roots. The average gain was 25 degrees of correction. Tongs were applied to the skull and were included postoperatively in a Minerva jacket. A jacket was again worn after removal of the tongs, and a collar worn thereafter for several months.

Eight deaths occurred, the causes of which were as follows: suffocation, one; ulcer or gastric erosion, two; cord thrombosis or injury, two; amyloid disease with renal failure, one; and anoxic encephalopathy, two. Complications encountered were: nerve-root irritation and pressure, four; intestinal obstruction, one; hematemesis, one; recurrent deformity demanding correction, three; and a few cases of ileus and psychic disturbance.

The author advised correction of spinal deformities at an earlier stage. He felt that reduction of deaths and complications comes with greater experience and foresight and thoroughly planned care.

Hazards of Steroid Therapy. Dr. Joseph J. Bunim [21] deplored the fact that the ready availability of the newer drugs makes laymen and doctors alike forget the proved value of old-fashioned treatment of rheumatoid arthritis. In his own practice, Dr. Bunim prefers to resort to steroids only when an adequate trial of conservative therapy has failed. Having reviewed the structure and properties of the newer synthetic derivatives (with particular attention to prednisone and prednisolone), Dr. Bunim reported upon a group of fifty-nine rheumatoid patients treated with the new drugs at the National Institutes of Health.

Ten of these patients exhibited good improvement, although cortisone had previously failed. Complications in the entire group included peptic ulcers in fifteen patients (of whom only three had to stop their medication), fractures in nine, psychosis in two, and in three, polyarteritis.

The latter complication had been seen in untreated patients, and is believed to be a rheumatoid arteritis that is an integral part of the whole picture. However, Dr. Bunim believed that necrotizing arteritis is more common in those patients who have been treated.

Of the total group of fifty-nine patients, eight died. It was thought that death was probably related to the drug therapy in two patients; perhaps related, in another three, and not at all related to treatment in the last three.

The Blood Supply of Tubular and Cancellous Bone. Dr. Ian Macnab [22] reported a study of the significance of periosteal circulation. By using the technique described by Trueta, the author showed that there are three distinct sources of arterial blood supply in resting adult tubular bone: the nutrient vessels, the metaphyseal vessels, and the periosteal vessels. He found, by injection techniques, that the only source of blood supply to the cortex was derived

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from the nutrient artery. There was free anastomosis between the metaphyseal vessels and the nutrient system, but practically none between the nutrient and periosteal systems. Under stress, however, the periosteum was found to be of vital importance. Death of bone does not result from interruption of the circulation of the nutrient artery; circulation is rapidly reestablished after destruction of the endosteal circulation from free anastomosis with the metaphyseal vessels.

If the endosteal circulation is destroyed and regeneration prevented by filling the medullary canal with wax, the entire cortex dies; and there is a massive formation of periosteal new bone which appears like extensive callus formation. Subsequently, the dead bone is revascularized and reossified by the subperiosteal new bone. When a bone is fractured, the endosteal circulation to the distal fragment is interrupted; however, there is no interference with the periosteal vessels which run transversely to the long axis of the bone. The periosteum can hypertrophy and seal the fracture gap. If the periosteum is destroyed, the fracture gap can be closed only by the endosteal callus formed by the vascular proximal fragment; and, since there is no periosteal seal, it is possible for fibroblasts to spread between the bone ends.

If a portion of the fibula was resected and replaced by a polyethylene tube, the tube acted as a barrier to the invasion of fibrous tissue and simulated a periosteal seal; if the gap remained unclosed or if a perforated polyethylene tube was used, fibrous-tissue invasion occurred which prevented union.

In a fractured bone, the endosteal circulation of the distal bone fragment is reestablished slowly. The dying distal cortex is revascularized by vessels derived from the periosteum which help to reconstitute the endosteal circulation. The ability of the periosteal vessels to restore endosteal circulation was demonstrated in an experimental double fracture. When the periosteum is stripped off and held away from the bone by an interposing membrane of tephlon, there was no periosteal vessel to vascularize the distal fragment; at the fracture site, dead bone opposed dead bone and there was no seal to bar fibroblastic infiltration. Experimentally, with the periosteum stripped, union did not occur. When there is severe initial displacement of a fracture with stripping and shredding of the periosteum, sealing of the fracture can occur only if the fracture is accurately reduced because union can occur only by endosteal callus.

While open reduction and internal fixation may delay union when the displacement is gross and the periosteum extensively stripped, securing and holding a hairline reduction with a screw actually speeds union. In instances in which internal fixation is indicated, great care in the exposure of the fracture site and particular care in holding the bone ends should be taken to protect the periosteum. If a medullary nail is used in patients with limb-shortening and destroyed periosteal circulation, there is little hope of union.

In discussion, Dr. Joseph Trueta [23] mentioned that a collaborator, Mr. J. D. Morgan, was publishing their results which differ somewhat from those of Dr. Macnab. He referred to the flow of blood in resting or normal conditions. In abnormal circumstances, such as those following a fracture, the participation of the three vascular systems in the process of reparative osteogenesis is altered and, in his experience, differed substantially from what Dr. Macnab reported. He believed that the periosteal system of vessels, provided it had not lost its connection with the tissues surrounding the periosteum particularly the muscles, played the main part in restoring bone continuity by callus formation and in keeping the cortex alive.

He pointed out these differences in results between his work and that of Dr. Macnab and his co-workers only to show that a lot more work and evidence is necessary before a final conclusion can be drawn on the relative contribution of vessels to the nourishment of long bones.

Non-Union of Fractures of Long Bones. Dr. Edwin F. Cave [24] noted that non-union of long bones is still a matter of considerable concern to surgeons, and that it is probably occurring more frequently because of the more general use of operative procedures. In an analysis of eighty-seven cases of long-standing ununited fractures which were treated by bone-grafting, sixty-five were closed fractures and twenty-two were open. It was discouraging to note that improper operative interference was high on the list in each group as a cause of delayed union or non-union. The differential diagnosis of delayed union and non-union was discussed in detail, both from the clinical standpoint and roentgenographic analysis.

The problem of an ununited fracture must be handled surgically by eliminating draining sinuses, if present; proper skin-grafting, if needed; and the introduction of bone with suitable operative technique appropriate for the individual patient. In considering what is appropriate, the author felt the surgeon should ask himself the following questions: What is the condition of the soft tissues about the fracture? Which bone and what part of that particular bone is involved? How long has non-union existed? What is the condition of the joints above and below the fracture site? Are the fragments in satisfactory alignment? To what degree is there sclerosis of the bone ends at the fracture site? To what degree is there osteoporosis of bone below, above, or both below and above the fracture site? To what degree is there bone loss?

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24. 264 Beacon Street, Boston, Massachusetts.

To what degree is there shortening of the injured bone? and If union can be established, will the patient have a useful extremity?

In answer to the last question, Dr. Cave, in his series of eighty-seven cases, noted that in most closed fractures of the long bones, when union is established, the extremity is useful. However, following severe open fractures, non-union presents a more pessimistic situation and prognosis.

Delayed Reduction of Fractures. Dr. John Royal Moore [25], Dr. A. F. Seifer, Dr. J. W. Lackman, and Dr. H. H. Steel.

Central Dislocation of the Hip. Dr. G. F. Pennal [26] presented his experiences in the treatment of a series of forty cases of central fracture of the acetabulum. Of this group simple fractures without displacement did well (twenty); comminuted fractures with persisting dislocation or distortion of the acetabular floor had disability (thirteen); open reduction maintained a satisfactory reduction (seven). The cases were classified as either anterior or posterior central dislocations. The anterior dislocations were approached through an abdominal retroperitoneal exposure. The major fragment to be replaced was the vault fragment; internal fixation was used to help maintain the reduction. The posterior central dislocation should be approached posteriorly. In five the result was quite satisfactory. There was one death; there was one redislocation in which no internal fixation was used.

In discussion, Mr. E. A. Nicoll [27] felt that good results from conservative treatment would occur in 80 per cent of the cases even with incongruity of the acetabulum, but that there were perhaps a few cases in which open reduction was advisable. Dr. Frank P. Patterson [28] felt that, in his experience, the roentgenographic appearance did not necessarily indicate whether or not the functional result would be good. He was not inclined toward open reduction of these fracture-dislocations.

Cervical Spine Injuries—Entities and Indications for Fusion. Dr. J. Neill Garber [29] discussed a group of forty fractures and dislocations of the cervical spine which he had divided into five categories. Each group contained patients having lesions which he believed should be treated by spine fusion following stabilization by skull traction. In the first group there were lesions of the atlanto-odontoid in which dislocation had occurred sufficient to cause paresis. There were ten patients in the over-all group, two of whom qualified, according to his definition, for the fusion operation; these had been fused successfully and had remained free of symptoms. The second group—dislocation without fracture consisted of five patients. He did not state how many of these were fused nor the results. The third group, consisting of three patients, was the so-called cock-up dislocation, in which the inferior articular processes of the dislocated vertebra rest upon the uppermost tips of the superior articular processes of the vertebra next below. Fusion was successful in two patients; they had no further symptoms. Eight patients made up the fourth group, called the traumatic spondylolisthesis group, in which there is a fracture of the pedicles and a moderate forward dislocation of the vertebral body with the posterior bone structures remaining in their normal relation to the vertebrae above and below. Those dislocations in this group which could be reduced by skull traction united, and fusion operation seemed unnecessary; on the other hand, those which could not be reduced by skull traction were fused. The fifth group, dislocation with fracture, contained thirteen patients of whom ten underwent spine fusion; the operations were successful and results satisfactory. The author included here those patients with posterior displacement of fragments of the compressed vertebral body into the neural canal. In this injury, fusion was done, following reduction by skull traction. One patient was in the sixth category—dislocation following extensive laminectomy. The author felt that if laminectomy is done for fracture-dislocation, surgical fusion should follow to prevent dislocation.

The Luschka Joints of the Cervical Spine—Anatomy, Physiology and Pathology. Dr. Edward L. Compere [30] discussed those joints that Hubert von Luschka described in 1858; the small joints between contiguous vertebrae, from the second cervical to the first thoracic vertebra. These measure two by four to three by six millimeters and are located at the extremities of the intervertebral discs on the posterolateral margins of the vertebral bodies. Luschka noted the presence of articular fibrocartilage, a joint capsule, synovial tissue, and fluid. Controversy prevails as to the existence of Luschka joints and their clinical significance. Frikholm contended that the joints represented fissures in degenerated fibrocartilage in the lateral margins of the intervertebral discs. Luschka stated that occasionally one finds in their place only loose connective tissue which is, as a rule, the case in the newborn.

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The author studied the anatomy and the pathological changes in specimens of Luschka joints obtained in the anatomy laboratory and at necropsy. Microscopic sections demonstrated all of the elements of a true joint in the cervical spine of adults. A lining synovial membrane cannot be found in most preparations, but synovial cells and fluid are present in all. They quote Maximow and Bloom that "the walls of the joint cavity" (any joint cavity) "are composed of a dense connective tissue whose cells are irregularly arranged, but seldom suggest an epithelium-like arrangement." This is true of the Luschka joints.

The function of the Luschka joints has not been clearly defined. It is assumed that they contribute to the wide range of frictionless motion in the cervical region, and the ascending lips in each Luschka joint provide osseous protection for the nerve roots and vertebral vessels and prevent posterolateral herniation of cervical intervertebral discs.

The joints have been demonstrated by anteroposterior roentgenograms with the neck extended and traction applied by a chin strap or with the patient prone and a small pad under the forehead. The author found no single technique to be satisfactory for all patients. Roentgenograms of the cervical spines of eighty-one asymptomatic patients were studied and of forty-nine individuals between the ages of fifteen and thirty-nine, one showed minimal arthritic changes in the Luschka joints. In thirty-two patients between forty and sixty-nine years of age, five showed osteophyte formation on the vertical facets (uncinate processes) of the Luschka joints. The author stated that this was secondary to narrowing of the intervertebral disc and cited eight references to corroborate this point.

An injury to the Luschka joints, with secondary deformity or arthritis, may cause compression or irritation of adjacent vertebral artery, cervical-nerve roots, or sympathetic nerves. Secondary reflex muscle spasm resulting from impingement or irritation of nerve roots by bone spurs on the Luschka facets may be one cause of the scalenus anticus syndrome. The author concluded that the Luschka joints are true articulations, offer protection to adjacent structures, and, when deformed by injury, disease, or the wear and tear of everyday activities, they may cause pain in the neck, shoulder, and arm, limitation of motion of the neck, or severe headaches from compression or spasm of a vertebral artery.

The Stored Homograft—Experimental Data and Clinical Implications. Cmdr. G. W. Hyatt [31] stated that the primary purpose of the tissue-bank laboratories of the National Naval Medical Center in Bethesda, Maryland, was to develop techniques of storage of homogenous tissues that would insure their satisfactory utilization as graft material at a later date. To a lesser extent, similar studies with regard to heterogenous grafts are under way.

A brief resumé of the current concept of the function of the bone graft was presented. In considering the relative effectiveness of different types of grafts, the author stressed the need for developing a standardized method of biological assay. He indicated that considerable thought had been given to this problem and pointed out that after adequate techniques are developed, one might then be able to study more effectively the confusing questions of the inductive influence of bone transplants and the immune response to homogenous grafts. He emphasized that, at the present time, different investigators are using different experimental conditions for trial procedures. Different experimental animals with unknown genetic backgrounds, grafts of different size, either cortical or cancellous type, different anatomical recipient sites, and other variations in technique create a staggering problem for the investigator to evaluate and provoke different interpretations of data.

Cmdr. Hyatt presented in detail the organization of the tissue bank and the techniques employed in processing freeze-dried homogenous bone. After removal of bone from the body under sterile precautions, the bone is frozen at —60 degrees centigrade and then freeze-dried for approximately fourteen days to remove all moisture except the protein-bound water. The bone is then slowly brought to room temperature and the container sealed *in vacuo*. The end product is bone with a moisture content of between 3 to 5 per cent at room temperature. The techniques used to check the remaining moisture content and the effectiveness of the vacuum were discussed. The freeze-drying process kills all bone cells but permits storage and shipping at room temperature. The types of cases, in which bone processed by this technique have been used, were listed.

The Development of the Histological Classification of Malignant Bone Tumors. Dr. H. A. Sissons [32] traced the accepted classifications of bone tumors from 1921 to the present. In 1921, the Bone Sarcoma Registry was formed. Two classifications were announced by that body, one in 1928 and one in 1939. Nearly twenty years have elapsed since the Registry's last published classification and in that period a number of changes have become necessary. In the field of benign tumors, the osteoid osteoma, chondromyxoid fibroma, benign chondroblastoma, nonosteogenic fibroma, and benign osteoblastoma have all been delineated from previously unrecognized mixtures of tumors, some of which were thought to be malignant. Dr. Sissons paid tribute to the work of Jaffe and Lichtenstein and emphasized the need for classification as a

31. National Naval Medical Center, Bethesda 14, Maryland.
32. Royal National Orthopaedic Hospital, 234, Great Portland Street, London W.1, England.

means of description of clinical behavior, prognosis, and investigation. He stressed that in some tumors the distinction between benign and malignant is not clearly cut and a certain number of tumors fall between the obviously benign and the obviously malignant criteria of histological and biological characteristics. This is particularly true for cartilaginous tumors and giant-cell tumors.

Dr. Sissons then presented a new classification based on the work of several authorities. The main characteristics of this classification are the separation of skeletal from non-skeletal elements in bone as the tissues of origin of tumors. Other features are a more detailed breakdown of benign tumors compared with previous classifications and a simplification of malignant ones. The classification is based on the tissue of origin, type of tissue, degree of differentiation, and behavior as a benign or malignant lesion. Examples were shown of the histological details which indicated the tissue of origin of some tumors and the difficulties encountered in some cases of specifically pin pointing the tissue of origin were pointed out. Examples were also given of the different types and degrees of differentiation seen in some tumors. The variability in individual malignant tumors was cited as an important area for future study and newer techniques such as the slab x-ray were mentioned for investigation in a more thorough manner. Dr. Sissons made a final comment concerning grading of tumors and felt that such grading was misleading at present and did not accurately indicate degrees of malignancy.

In the discussion, Dr. J. Vernon Luck [33] emphasized the absence in any classification now used of etiological evidence and pointed out that this type of investigation must be fruitful before classification will be anything other than empirical. He added to Dr. Sissons' classification the entity he called giant-cell fibroma. He also cited many newer techniques to be used in the study of individual tumors.

In closing, Dr. Sissons again cited areas of difference of opinion on the classification of tumors and mentioned the need for periodic revisions of classifications. He also cited the need for studies on transplantation culture as an aid in tumor investigation.

Diagnosis and Treatment of Secondary Chondrosarcoma. Mr. Roland Barnes [34] said that secondary chondrosarcoma originates on a pre-existing chondroma or osteochondroma. He had studied the clinical features of chondrosarcoma occurring in multiple exostosis and Ollier's disease and found, with one exception, that malignant transformation always occurred in adult life. In Ollier's disease, the patient was often over forty years of age.

In multiple exostosis, the most vulnerable sites are the pelvis, vertebrae, femora, and humeri. Chondrosarcomata occurring in Ollier's disease were more widely distributed in the skeleton, although the pelvis and femora were favorite sites. Growth of an enchondroma or osteochondroma in adult life is evidence of malignant transformation. A painful enchondroma in a long bone of an adult is probably malignant, and the diagnosis is certain if it has penetrated the cortex of the bone. The benign character of enchondroma in phalanges, metacarpals and metatarsals was emphasized, even though they appear ominous on microscopic examination.

Enucleation fails; the treatment is excision by a wide margin or by amputation. If recurrence occurs after resection, then, in most cases, amputation is indicated. Frequently, histological indication of malignant transformation does not occur; the criteria of malignant transformation must come from correlation of roentgenograms, clinical examination, and gross pathological characteristics. The prognosis was the most encouraging of any of the malignant tumors of the osteogenic series.

In closing, Mr. Barnes stated that the life of the patient frequently is in the hands of the first surgeon to treat the patient, and too many lives are being lost to save too few limbs.

Surgical Treatment of Bone Sarcomata. Col. M. S. Thompson [35], Col. S. J. Ritchey [36], Capt. T. B. Horan [37], and Capt. G. I. Baker [38] presented a follow-up study on 169 of 173 patients with primary malignant skeletal tumors treated at the Walter Reed Army Hospital. The authors reported the five-year survival rate of patients with the following tumors treated by biopsy and amputation: osteosarcoma, 11 per cent; chondrosarcoma, 33 per cent; fibrosarcoma, 54 per cent; and Ewing's sarcoma, 8 per cent. Because of the poor survival rate, especially with osteosarcomata, the authors now advocate the use of irradiation therapy, both before and after biopsy. Ewing's sarcoma was treated in most instances by irradiation only. Therapeutic amputation is delayed for from three to six months; if metastases develop, it is not performed.

Recent Experiences with Treatment of Osteogenic Sarcomata. Dr. William T. Green [39] presented a detailed analysis of the treatment and results of approximately thirty-five osteogenic sarcomata. All of the patients were children cared for at The Boston Children's

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34. Western Infirmary, Glasgow, Scotland.
35. 441 Burr Road, San Antonio, Texas.
36. 98 General Hospital, APO 34, New York, New York.
37. Walter Reed Army Hospital, Washington, D. C.
38. Walter Reed Army Hospital, Washington, D. C.
39. 300 Longwood Avenue, Boston 15, Massachusetts.

Medical Center. The study compared treatment and results prior to and after 1946. Prior to 1946, the procedure was biopsy and amputation, but all of the patients died of metastases. Two conclusions were drawn: (1) that early amputation used alone is not an effective treatment and (2) a revision of this treatment could not cause worse results.

The revision of the treatment since 1946 consisted of x-irradiation before biopsy and amputation. This revision was in part prompted by Ferguson's concept of a quiet period in malignant tumors. During this period roentgen therapy might influence the case favorably. The finding by several investigators, of malignant cells circulating in the blood stream, has led to the postulate that it may be the soil and not the seed that leads to the successful growth of metastatic foci. This theory includes the view that the primary tumor may create host immunity to metastatic growth and when this immunity is overwhelmed metastases occurred.

The treatment since 1946 has consisted in:

1. Moderate doses of x-irradiation, approximately 1400 r, given within one week and followed promptly by biopsy. This dose of irradiation has not complicated histological interpretation.

2. After biopsy heavy irradiation, averaging 6000 r, given over a period of approximately one month. The day after the irradiation has been completed amputation was carried out well above the tumor.

3. Chemotherapy has been given on general principles.

Results have been encouraging in the various types of osteogenic sarcoma. Of twenty-three patients admitted before metastases had occurred, fourteen were followed for more than two years. Six of the fourteen died, while eight survived, six of them for five years or more.

Local Excision of Bone Tumors and Prosthetic Replacement. Mr. H. Jackson Burrows [40] and Dr. J. T. Scales [41] discussed their experience with regional resection and insertion of a prosthesis in isolated bone tumors in a carefully selected, and therefore small, series including three central chondrosarcomata, a recurrent giant-cell tumor, and one isolated thyroid metastasis. Difficulties included late breakage of one acrylic prosthesis (now superseded by cobalt-chrome-molybdenum alloy), failure of the junction with bone (also after some years, and an unsolved problem), and delay in fabrication. On the other hand, compared with bone-grafting, the insertion of a prosthesis gave a shorter convalescence and resulted in better preservation of function.

The most dramatic result was illustrated by a moving-picture film showing a regional knee resection for a recurrent giant-cell tumor of the femur. The film demonstrated surprisingly good function three years and four months after the insertion of a completely metal knee joint.

Mr. Burrows, who referred to the chondral tumors and the giant-cell tumor as locally malignant, considered the cases too few and the duration up to seven years too short for an assessment of this "experiment in conservative surgery".

Dr. William H. Bickel [42], in his discussion, asked Mr. Burrows how he defined "locally malignant tumors", and presented interesting evidence in regard to malignant-tissue change. Regional resection and prosthetic replacement is rarely advisable in light of our present knowledge of neoplasia and the uncertainty which exists in regard to the permanent function of implanted foreign materials.

Mr. Burrows replied "tumors that grow relentlessly and recur readily but do not disseminate early".

Orthopaedic Aspects of Myelomatosis. Mr. D. Lloyd Griffiths [43] pointed out the frequency of incidence of multiple myeloma. Awareness of this incidence and a high index of suspicion enables one to make a higher percentage of positive diagnosis. The disease is more common than any primary malignant tumor of bone and may well be more common than the total of all primary malignant tumors of bone. Many cases do not present a typical textbook picture. The disease should be suspected in older patients complaining of pain in the back and especially if there is roentgenographic evidence of osteoporosis or areas of radiolucency in bone.

A series of over sixty cases of myelomatosis was reported. In four-fifths of the patients the symptoms suggested an orthopaedic problem. In one-third, the first symptom was pain in the back. Other complaints were shoulder or arm pain, or the presence of a mass. Sciatic pain and pathological fractures of the long bones were not common symptoms.

The presence of radiolucent areas in the bones, a disturbance of the albumin-globulin ratio of the blood proteins, in addition to an elevated rate of sedimentation of the blood erythrocytes, and other findings, suggest the diagnosis of myelomatosis. The diagnosis can be confirmed only by biopsy. In the series reported by Mr. Griffiths, the biopsy specimen usually obtained by aspiration of marrow either from the iliac crest or the sternum usually gave useful if not confirmative evidence.

Treatment with roentgen therapy was beneficial in a number of patients with myelomatosis. Operative decompression had relieved paraplegia in two patients in this series.

40. 25, Upper Wimpole Street, London W.1, England.
41. 17, Brockley Avenue, Stanmore, Middlesex, England.
42. Mayo Clinic, Rochester, Minnesota.
43. 24, Carr Wood Road, Bremhall, Cheshire, England.

Parosteal Osteoma of Bone. Treatment. Dr. Murray M. Copeland [44] and Dr. Charles F. Geschickter [45] emphasized, as in previous reports, that parosteal osteoma is a clear-cut entity, which may be either benign or malignant. Recently, the tendency to consider it a malignant or potentially malignant tumor has increased. Parosteal osteoma can resemble myositis ossificans, both roentgenographically and histologically. However, myositis ossificans tends to manifest itself after trauma, reach its maximum size in six to twelve weeks, and then remain passive. Parosteal osteoma tends to have a much longer history and slowly continues to grow. There is seldom a history of trauma adequate to cause myositis ossificans. The evolution from benign to malignant form may take place over a period of several years. The authors believe that the tumor arises from bands of skeletal blastema displaced from primitive periosteum. The peak age incidence is from the first to the fourth decade. In ten patients of the twenty-two cases reported, the tumor was located at the posterior surface of the lower portion of the femur, bulging into the popliteal space. In most cases, the roentgenogram is so characteristic because of the rounded masses of ossification projecting into the soft parts (some of the smaller of them lying free of the bone) and because of the thickening of the underlying periosteum and cortex which are densely sclerotic that the diagnosis can be suspected from the films and confirmed when the pathological report shows benign fibrosis and new-bone formation. In such instances, primary excision or resection is warranted. Such cases should be watched and radical measures instituted at the first sign of recurrence. Microscopically, the tumor may have aspects of myositis ossificans, spongy osteoma, osteofibroma, and low-grade fibrosarcoma. In many instances, there will be only scattered small foci showing malignancy. These foci are easy to overlook. A biopsy is likely to be reported as benign histologically even when the process has reached a malignant stage. This report has a tendency to give the surgeon and pathologist a false sense of security, leading to under-diagnosis and under-treatment.

Generally speaking, the results from local excision or resection have not been good. Amputation is indicated in the management of these cases, and will cure more patients than temporizing surgical excisions. If the process recurs after a local excision, it is likely to recur in a more malignant form. The over-all recovery rate in the authors' series was 60 per cent, indicated by five-year cures. The tumor should never be enucleated. Occasionally there is a place for local resection. Amputation should be carried out if histological examination shows evidence of anaplasia; or, where the mass is large and steadily growing; or, where the mass has invaded the underlying bone; and finally, where there is a recurrence after local resection. A review of cases reported by the authors and those in the literature indicates that temporizing treatment has cost many lives. Dr. Copeland and Dr. Geschickter estimated that with proper early treatment there should be a 90 per cent chance for cure. The prognosis in this entity is better than for any other type of bone sarcoma.

Lumbosacral Interbody Fusion. Mr. George F. Dommisse [46] reported his results in the treatment of thirty-five patients with spondylolysis and spondylolisthesis and thirteen patients with other types of spinal instability; all were treated by interbody fusion. These forty-eight patients had been followed from seventeen months to ten years, an average of four years. The surgical technique employed, including an approach through the lateral mass of the sacrum to the lumbosacral interspace, was described as well as the postoperative management. The results by clinical assessments were good or very good in 81 per cent, improved in 11 per cent and worse in 4 per cent. Fusion as determined roentgenographically occurred in 50 per cent, failed to occur in 42 per cent, and was undetermined in 8 per cent. However, if only the last twenty-four patients were considered, successful fusion occurred in 76 per cent. The complications recorded included: failure of fusion in twenty patients (five undergoing further operation), retropulsion of the graft in three patients (all were subjected to reoperation), foot-drop in two patients (the cause not established), intractable sepsis in one patient, pulmonary embolism in one patient, and venous thrombosis of the leg in one.

There were no deaths. The author concluded that interbody fusion can be achieved in a satisfactory percentage of cases, that the indications for this procedure are limited to intractable backache particularly with spondylolisthesis, and that in the event of failure of interbody fusion a subsequent posterior fusion has a 75 per cent chance of inducing successful fusion both anteriorly and posteriorly.

The Organization of the Components of Connective-Tissue Matrices that Normally Calcify. Dr. R. A. Robinson [47] stated that five connective-tissue matrices normally calcify. All of these have a fibrillar component. Bone, dentine, cementum, and epiphyseal cartilage have collagen fibrils. In bone, dentine, and cementum, the collagen fibrils are large, and in bone they may be very closely packed. In epiphyseal cartilage the fibrils are very small and their

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47. The Johns Hopkins Hospital, Baltimore 5, Maryland.

banding is difficult to demonstrate. They are often very loosely packed in the matrix. Enamel matrix contains keratin, shown by x-ray diffraction studies to be fibrillar although present electron micrographs do not demonstrate as clearly the fibrillar nature of this matrix. Electron micographs show that calcification begins in relation to fibrils in bone, dentine, and epiphyseal cartilage. This can be demonstrated in rachitic or normal osteoid. The crystal (C) axis is oriented to the collagen long axis when the collagen fibrils are closely packed as in bone. The crystal axis is oriented to the long axis of the keratin fibrils in enamel even when there is a very low concentration of keratin. Electron micrographs show that the collagen fibrils in bone and dentine are calcified internally as well as externally. The author emphasized two concepts that are applicable to the calcification process of all normally calcifying organic matrices. First, there is the concept that the hydroxyapatite crystal nucleation sites are related to the fibrillar portion of the matrices and perhaps to a specific amino acid prosthetic group. Secondly, he mentioned the concept of the loss of water both from the interfibrillar cement substance and from the intrafibrillar space during the calcification process. In other words, the organic matrix is not removed to make room for the crystals during calcification, instead, the hydration of the matrix is reduced.

The Macromabular Aggregation State of Collagen and Its Relation to Calcification. Dr. Melvin Glimcher[48].

The Anatomy of Bone Cysts. Dr. Lent C. Johnson[49] and Dr. Robert G. Kindred[50] presented a paper on the anatomy of the walls of bone cysts studied in 200 specimens in the Orthopaedic Registry of the Armed Forces Institute of Pathology. All appeared at surgery as hollow cavaties filled with fluid or air. The cysts were obtained from patients ranging from eight months to seventy years of age, the majority of whom were less than forty years. Half of the lesions were in the femur, humerus, and tibia (25 per cent in the mid-shaft and 75 per cent in the metaphysis and adjacent shaft). There were no complicating fractures in half of the cases and a number of cysts were resected intact within the surrounding bone.

The authors pointed out that cyst linings varied from a few micra to a centimeter in thickness. When thin, the lining resembled a juxta-articular ganglion; when thick, a bursa. Almost invariably, they encountered an additional parietal nubbin of tissue which projected into the cyst or lay in the adjacent bone marrow. Grossly, the nubbin was glistening white, firm, rubbery, and resembled cartilage. Microscopically, it was composed of the following four elements of primitive mesenchymal tissue, any one of which might predominate:

1. When numerous vascular channels were in the wall, resembling an angioma or glomerulus, clear, watery fluid tended to fill the cyst.

2. When material like Wharton's jelly of the umbilical cord, resembling a myxoma, was prominent the contents of the cyst tended to appear gelatinous.

3. When a delicate fibrillar material of scant cellularity resembling areolar connective tissue (containing puddles of protein-rich fluid in the interstices) was dominant, the cyst contents tended to be serous. Compaction of the fibrillar elements produced the usual fibrous cyst wall. Occasional foci of osteoid, chondroid material, and giant cells were noted in the fibrillar portion of the nubbin.

4. Usually undifferentiated mesenchymal cells which could be traced through lipoblasts and xanthoma cells to mature fat cells, as in lipoma, were present and when predominant the cysts contained an oily yellow fluid.

Accordingly, the authors described the parietal nubbin as an angiomyxofibrillar lipoma which resembles the angiofibrolipomata of soft tissue. The lipomatous element was predominant in more than half the cases. Ischaemia of this fat led to focal calcification of the margin; infarction produced dead fat cells within the cavity. Cholesterol ester slits with a foreign-body giant-cell reaction were common about the margin wall. In several instances a classical lipoma within bone bordered the cyst; in one case an early liposarcoma was present in the cyst wall. Serial biopsy specimens in another demonstrated the rapid development of a large cystic cavity from a small, solid angiomyxofibrillar lipoma. The presence of such a dysplastic tumor-like nubbin outside the cavity wall (and thus not in vision at operation) accounts for recurrences after surgical obliteration of the cavity.

Rheumatoid Synovial Cyst of the Hip. Dr. Mark B. Coventry[51], Dr. Howard F. Polley[52], and Dr. Alan D. Weiner[53] reported on three cases of cysts, lined by synovial membrane, which were present in the hip region of patients with advanced rheumatoid arthritis. The patients were between fifty-six and sixty-three years old, and had had arthritis for fifteen to

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thirty years. The cysts, of one-half to two years duration, were painless masses in the inguinal region. When each cyst was aspirated, cloudy but sterile fluid was obtained. The cysts were excised in two patients and in one, an additional cyst, which subsequently occurred on the opposite side was also excised. His cysts were large enough to cause distal lymphoedema. Those cysts which were explored, communicated with the hip joint and were located in the region of the iliopectineal bursa.

The authors presented three theories as to the etiology of these cysts: (1) that overproduction of synovial fluid distends the joint capsule; (2) that the cyst may be the iliopectineal bursa; and (3) (which the authors think least likely) that the cyst represents necrosis of a subcutaneous periarticular rheumatoid nodule.

The discussion was opened by DR. W. D. COLTART [54] who cited a British report of such a cyst. The discussion was concluded by DR. PHILIP D. WILSON [55] who pointed out the similarity between these synovial cysts and those at the popliteal area in the rheumatoid patient. He raised the question as to whether there may not be some relationship between the appearance of these cysts and the massive use of cortisone.

The Bone Changes in Sickle-Cell Anaemia and Its Genetic Variants. MR. J. S. R. GOLDING [56], MR. J. E. MCIVER [57], and MR. L. W. WENT [58] presented information concerning the orthopaedic and roentgenographic features of sickle-cell anaemia and its genetic variants. Recognition of these variants had made necessary a reappraisal of the skeletal changes formerly attributed to sickle-cell anaemia. The series presented contained fifty-one cases of sickle-cell anaemia, nineteen cases of sickle-cell hemoglobin disease, and two cases of sickle-cell thalassaemia disease. Bone changes are classified into the following groups: (1) those due to marrow hyperplasia; (2) those due to avascularity from embolism or thrombosis; (3) those due to growth disturbance; and (4) those due to superimposed infection. Group I occurred primarily in the patients with sickle-cell anaemia most frequently in the vertebrae and skull, although long bones also were involved. Group II occurred mostly in patients with sickle-cell hemoglobin C disease with occasional incidence in sickle-cell anaemia, and one patient with sickle-cell thalassaemia disease. The hips were the most common sites affected, and resembled Perthes' syndrome in course and response to treatment. Vertebrae, humeri, and femora also showed avascular foci, often without symptoms. Group III changes could be generalized or localized, the growth retardation being found only in the cases of sickle-cell anaemia. The patients in Group IV showed infection mainly in long bones and immediately following crises. Salmonellla was found in two of eight cases, seven being sickle-cell anaemia.

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BEDFORD FOREST BOYLSTON

1916-1958

Bedford Forest Boylston, Chairman of the Orthopaedic Section at Baylor University College of Medicine died at the M. D. Anderson Hospital on March 22, 1958 as a result of lymphosarcoma.

Biff Boylston, the son of Leon L. Boylston, was born on September 25, 1916, at Aiken, South Carolina, where he subsequently attended public schools. He graduated from Duke University in 1937 and received his medical degree from Jefferson Medical College in 1941. Dr. Boylston served his internship and eventually became house surgeon at Bellevue Hospital in New York. He continued his training as assistant resident and fracture resident at Columbia Presbyterian Hospital in New York City. Following the completion of his duty in the Naval Medical Corps he had three years of residency in orthopaedic surgery in Boston at the Boston Children's Hospital and Massachusetts General Hospital. Upon completion of his formal training, he joined the Orthopaedic Section of Baylor University College of Medicine and entered part-time private practice.

Some of Biff's greatest assets were his dynamic personality, academic vitality, and invigorating interest that attracted students of surgery to him constantly. He continued to be even more active after being aware of his malignant neoplasm. He was President of the Houston Orthopaedic Club at the time of his death.

R. P. E.

News Notes

The next Annual Meeting of **The American Academy of Orthopaedic Surgeons** will be held in Chicago, Illinois, January 24 through 29, 1959.

The Annual Meeting of the **American Society for Surgery of the Hand** will be held in Chicago, Illinois, January 23 and 24, 1959.

The **Virginia State Orthopaedic Society** held its annual business meeting and luncheon on October 13, 1958, with Dr. J. Hamilton Allen presiding. Dr. George G. Hollins, Jr., was elected President; Dr. William M. Deyerle, Vice-President; and Dr. Richard Fisher, Secretary-Treasurer. The annual scientific meeting will be held in Arlington in April 1959.

The Nineteenth Annual Meeting of the **Orthopaedic Guild** was held in Richmond, Virginia, on October 17 and 18, with the members from Richmond, Dr. R. D. Butterworth and Dr. Beverley B. Clary acting as hosts. Twenty-seven of the thirty-six members were present. Following the scientific program, the members went by bus to Williamsburg.

The Forty-sixth Annual Meeting of **The Clinical Orthopaedic Society** was held in Denver and Colorado Springs, Colorado, October 2, 3, and 4, 1958. The newly elected officers of the Society are: Dr. Atha Thomas, President; Dr. Robert C. Robertson, Vice-President, and Dr. Charles H. Frantz, Secretary-Treasurer.

The **Tennessee State Orthopaedic Society** held its Tenth Annual Meeting on March 22 and 23, 1958, at Vanderbilt University Hospital, Nashville, Tennessee. Thirty-six members and twelve guests were registered. Dr. Marcus Stewart presented a moving picture on an anterior approach to the cervical spine, Dr. S. Benjamin Fowler presented a moving picture on a new method for correction of the cavovarus foot deformity by osteotomy of the first cuneiform, plantar fasciotomy, and transfer of the tibialis anterior. Dr. John J. Killeffer presented a moving picture on the technique of Peabody's operation. A symposium on fractures of the tibia was presented by members of the Nashville Orthopaedic Society. Dr. Guy Caldwell, New Orleans, Louisiana, the guest speaker, discussed the future of orthopaedic education. Dr. R. Beverley Ray was elected President; Dr. Moore Moore, Jr., Vice-President; and Dr. A. H. Crenshaw, Secretary-Treasurer. The 1959 meeting of the Tennessee State Orthopaedic Society will be held in Memphis.

At the Annual Meeting of the **Mid-Central States Orthopaedic Society,** held at the University of Arkansas Medical Center, Little Rock, Arkansas, Dr. Werner P. Jensen, Omaha, Nebraska, was elected President. The next annual meeting of the Society will be held in Omaha, Nebraska, April 1959.

The **South Carolina Orthopedic Association** met September 6, 7, and 8 at Myrtle Beach, South Carolina. At the business meeting Dr. William Boyd was elected President; Dr. A. T. Moore, Vice-President; and Dr. George Dawson, Secretary-Treasurer.

Dr. Walter P. Blount of Milwaukee, Wisconsin, was the guest speaker at the Annual Meeting of the **Georgia Orthopedic Society,** held at The Cloister, Sea Island, Georgia, September 13 and 14, 1958.

The **Minnesota-Dakota-Manitoba Orthopedic Society** met at Rapid City, South Dakota, on September 12 and 13. The next Annual Meeting will be held in Winnipeg under the Presidency of Dr. Elmer S. Jones.

The Part I examinations of the **American Board of Orthopaedic Surgery** will be held March 26 and 27, 1959, in Washington, D. C., Denver, Colorado, and Rochester, Minnesota.

The Board of Trustees of the **Orthopaedic Research and Education Foundation** has approved the following grants. The awards, totaling over $10,000, were as follows:

Joseph M. Janes, M.D., Mayo Clinic, Rochester, Minnesota: Inducting Osteogenic Sarcoma;

Don H. O'Donoghue, M.D., University of Oklahoma Medical Center, Oklahoma City, Oklahoma: Histological and Clinical Analysis of the Reparative Process Taking Place in Injured Ligaments of the Knee in Dogs;

Alvina O. Sabanas, M.D., Northwestern University and the Armour Institute, Chicago, Illinois: A Knee-Joint Prosthesis of Teflon and Steel;

Bertrom M. Kummel, M.D., Newark Beth Israel Hospital, Newark, New Jersey: An Evaluation of the Gallstadius Experiment;

Kirk J. Anderson, M.D., University of Washington School of Medicine, Seattle, Washington: The Effect of Particle Size of the Homogenous-Bone Transplant on the Host Tissue Vascular and Inflammatory Reaction;

Charles F. Gregory, M.D., University of Texas Southwestern Medical School, Dallas, Texas: Immune Response and Inductor Capacity of Homologous Foetal-Bone Transplants.

The **Second Pan-American Congress on Rheumatic Diseases** will be held in Washington, D. C., in conjunction with the Twenty-third Annual Meeting of the American Rheumatism Association, June 2 through 6, 1959. Dr. Richard T. Smith, West Point, Pennsylvania, is Secretary-General of the Congress.

Col. John D. Blair, M.C., U. S. Army, has been named Chief of the Orthopaedic Service at Walter Reed Army Hospital, Washington, D. C. He succeeds Col. Milton S. Thompson.

Dr. Joseph H. Boyes, M.D., Los Angeles, California, will address the Boston Orthopaedic Club on Tendon Transfers in the Hand, December 15, 1958.

Book Reviews

TUMORS AND TUMOROUS CONDITIONS OF THE BONES AND JOINTS. Henry L. Jaffe, M.D. Philadelphia, Lea and Febiger, 1958. $18.50.

The long awaited text on bone tumors by Jaffe was bound to be an outstanding treatise. For two decades or more Jaffe has been perhaps the outstanding expert in the pathology of bone. He has written a large number of important papers, some of them classics, covering many phases of the subject. Evidently these were fore-runners of the present authoritative text. The summation of his tremendous volume of experience and knowledge constitutes a definitive reference work for the use of pathologists as well as orthopaedists. It deserves the highest praise and it will undoubtedly become the most popular reference work on the subject. To be reviewed in a way which will bring out its special features, it should be compared with other books in the field.

Jaffe brings a new concept to the presentation of bone tumors. He dispenses with the classifications which list the kinds of cells and their forebears and considers the benign and malignant tumors arising from each cell type. Such classifications (as by Ewing in 1939 and Lichenstein in 1952), he feels, do not fit the facts well enough. Instead he classifies each tumor, not only by its histological characteristics, but also by its clinical and roentgenographic aspects; in short, by its total biological behavior. This fruitful approach allows important ideas to be introduced. For example, the variability of histological appearance of giant-cell tumors, or of multiple enchondromata, may indicate either benign-ness or a spectrum of degrees of malignant behavior of the tumors. The new idea is that each of these entities encompasses a certain stated amount of variation in pathological as well as clinical characteristics. A particular tumor can then be recognized as a member of a family group, and a prognosis assigned on the basis not merely of cytological data but on the total picture. Another example is the portrayal of the aneurysmal bone cyst. Whether or not one agrees that the "blow out" appearance roentgenographically warrants the term *aneurysmal*, despite the absence of a true aneurysm, it cannot be denied that it is difficult to assign a cell of origin to the tumor. With the new concept this is not necessary—for proper diagnosis, treatment, and prognosis one need only recognize and properly evaluate the essential clinical and pathological aspects.

This denial of classical classifications disturbs the pattern of organization of the book so that each chapter, describing a single entity, seems unrelated to the next. Probably the discontinuous pattern is in keeping with the ununified subjects considered, and certainly it is tempered by explicit cross reference in the text wherever necessary and by a good bibliography and index.

Scarcely a decade ago, only one American textbook on bone tumors existed: Geschickter and Copeland's highly controversial book published in 1935. Even in its more recent revision, this text does not compare with Jaffe's in explicit points of roentgenographic and clinical and especially cytological differentiation of the different tumors. The more recent book of Coley (published in 1949) may serve as a general text for students but it contains none of the fine points of differential diagnosis of histological details which are the best feature of Jaffe's book. Several entities, including a few described in the last decade, are absent in Coley's book, for example, aneurysmal bone cyst; no such defects are found in Jaffe's text. Lichtenstein's book (published in 1952) resembles Jaffe's in that it is also based primarily on personal observations. It is half the size of Jaffe's, however, and cannot possibly cover the many subjects in similar detail. Thus Lichtenstein devotes two pages of text to multiple enchondromatosis while Jaffe has seven. Lichtenstein's illustrations are correspondingly fewer and less varied, while Jaffe's selection of roentgenograms and photomicrographs is simply superb. Jaffe frequently illustrates a point by briefly citing a personally observed case, for example, how an enchondroma was suspected of malignant change and how often this change occurs. Lichtenstein does this only occasionally. Lichtenstein's book, does not address itself to many specific points, because of limitations of space, and leaves unmentioned such entities as juxtacortical osteogenic sarcoma and chondroma and passes over others as non-tumorous, for example, bone cysts. Altogether Jaffe's book is much more suitable for ready reference work while Lichtenstein's, if brought up to date, would be more fitting for reading and studying by students and practitioners.

A final comparable work, Dahlin's book published in 1958, is also similar to Jaffe's and is necessarily less detailed. Its emphasis however is so different that it serves an entirely different purpose, namely, that of summarizing and recording the Mayo Clinic's case material. Differential histological diagnoses in Dahlin's book as contrasted with Jaffe's are short and succinct, sufficient to give a basic idea of the entity being discussed but insufficient for reference purposes. The helpful chapters that Jaffe includes on how biopsy should be done and evaluated, the effects on the skelton of different metastatic or contiguous tumors, and the entire field of tumorous conditions of joints and related structures necessarily are not covered in Dahlin's small book, nor, for that matter, in most of the others cited.

With its many virtues, Jaffe's text also has certain defects. The first is the ponderous and redundant style. While no grammatical atrocities are committed, the frequent, repetitious use of unnecessary words or phrases, such as specifically and as to sex incidence, offends the sensi-

tive reader. Certainly there are better alternatives to bone being porotified and lesional tissue being cystified. A second defect is a rather incomplete consideration of the carcinogenic effects of bone-seeking radioisotopes. Few details are given and the bibliography seems a little too narrow in scope for a topic of such importance in the field. Third, it does not seem proper to include, on equal status with well delineated lesions, the so called desmoplastic fibroma, a new entity, based on five hitherto unreported lesions. The propensity of the ordinary desmoid to recur or to become malignant is hardly exhibited by this group of tumors, which most pathologists probably call simple fibromata.

However, in summary, this book is sure to be the standard reference work on this subject for many years to come. Its useful bibliography, detailed index, and clear subheadings enhance its utility. But most of all, the outstanding experience and deliberate design of the author to provide pathologists and orthopaedists with the best reference work available on bone tumors will make this work a necessary part of every library.

Jonathan Cohen, M.D.

ORTHOPAEDIC DISEASE. PHYSIOLOGY, PATHOLOGY, RADIOLOGY. Ernest Aegerter, M.D., and John A. Kirkpatrick, Jr., M.D. Philadelphia, W. B. Saunders Company, 1958. $12.50.

This is an excellent textbook for anyone interested in the physiology, pathology, and roentgenographic aspects of bone disease. This is not truly a comprehensive orthopaedic textbook, since disorders of the neuromuscular system are not discussed. This deficit and the fact that it does not concern itself with the therapy of orthopaedic conditions in no way detract from the excellence of the book. The authors have written this text to assist the various specialties concerned with the interpretation of bone disease in an understanding of all the factors contributing to the clinical picture. It should prove to be a useful book for the pathologist, since the roentgen aspects of the lesions are well portrayed as well as the clinical features. Roentgenologists should benefit by having a better understanding of the disturbed physiology and pathological process underlying the various changes in the bone. The introductory chapters are concerned with a consideration of the embryology and history of normal connective tissue and bone. This is a very good monograph in itself.

The second section is concerned with the congenital anomalies and developmental disorders which includes the congenital anomalies, the metabolic disorders, the abnormalities of growth, and the disturbances of lipid metabolism.

The third section is concerned with disturbances affecting the normally formed skeleton. The repair of fractures, circulatory disturbances, metabolic diseases, infections, and endocrine disorders are presented. The last section discusses tumors involving bone.

The material is presented in a logical, concise manner and is well illustrated. The reproductions of roentgenograms and microscopic sections are very good. The authors should be commended for presenting a difficult subject in such splendid fashion.

David S. Grice, M.D.

SKIN GRAFTING. James Barrett Brown, M.D., and Frank McDowell, M.D. Ed. 3. Philadelphia, J. B. Lippincott Company, 1958. $15.00.

Those readers familiar with the two earlier editions of *Skin Grafting* by Brown and McDowell will find this up-to-date Third Edition of even greater value. There is no doubt that this classic is a complete, carefully thought out, and valuable treatise on all phases of the indications for, and the uses of, free skin grafts and flaps. Those interested in the general aspects of reparative and reconstructive surgery, especially following trauma, will find it one of the most helpful volumes that has appeared in recent years. A perusal of the table of contents will excite the casual reader and will be a source of many ideas and useful information to the puzzled surgeon faced with a specific problem.

In the first edition *of Burns* was added to the title. The care of the severely burned still occupies a place of major importance in this monograph—quite in keeping with the magnitude of the burn problem facing the surgeon today. Much has been written in the past two decades about burns, with the major emphasis on fluid replacement and supportive therapy. Unless there is a major catastrophe in which blood or plasma are unavailable, this problem is largely solved. The real challenge continues to be the early and late care of the local wound. The authors quite correctly point out that in only a few reports has late rehabilitation been emphasized and final results reported. Brown and McDowell are among the few who have presented a complete picture of the management of the severely burned patient from the onset of the injury to the final rehabilitation.

The scope of this monograph is so vast that no reviewer could possibly do it justice. Suffice it to say that after an introductory review of the methods of plastic surgery, skin-grafting, and pedicle flaps, the problems of repair of specific areas, such as arms, hands, feet, face, and eyelids, are taken up in individual chapters. In addition to this broad spectrum of areas of the body, specific types of injury are described, including farm, industrial, radiation, and atomic trauma. The preservation of homogenous grafts and the establishment of skin banks are discussed at some length and some of the shortcomings of skin grafts are indicated and discussed.

This monograph by two of America's leaders in plastic surgery should prove a valuable source of information and reference to all surgeons.

Bradford Cannon, M.D.

To Work in the Vineyard of Surgery. The Reminiscences of J. Collins Warren (1842-1927). Edited, with Appendices, Notes, and Comments, by Edward D. Churchill, M.D. Cambridge, Harvard University Press, 1958. $6.00.

J. Collins Warren had the fortune to be born shortly before the advent of anaesthesia, to be educated in medicine during the development of bacteriology and aseptic surgery, and to have practiced surgery during the period of the greatest advances in its applicability to medical practice. He was born into a family noted for its medical practitioners and lived in Boston, one of the foremost centers for medical affairs in America. With his talents and heritage, therefore, he had the opportunity to perform a leading role in the development of the Massachusetts General Hospital, and, specially, in the transformation of Harvard Medical School with its affiliated hospitals into the outstanding medical center it is today. His reminiscences make fascinating reading, particularly to those who are interested in the history of surgery, of Harvard Medical School, and of Boston. Churchill, present Surgeon-in-Chief at the Massachusetts General Hospital has edited and annotated this work in such a way that it held this reviewer's interest right through, including every single footnote and appendix. Not that the footnotes and appendices are pedantic references—not in the least, they often provide a sociological or historical framework for proper understanding of the medical events as Warren relates them. Warren took care to avoid personal references or characterizations either in relation to himself or to his contemporaries. The factual narrative therefore seems impersonal and without prejudice and can only rouse the reader's imagination about what kind of man Warren must have been. The setting of his childhood and youth was such that medicine was the obvious profession for him. He describes vividly his first view of an operation when he was thirteen years old, his father being the surgeon and the operation being the removal of a maxilla. The usual training of doctors at that time, involving perhaps eighteen months of medical school not preceded by college or requiring entrance examinations for admission, was seldom deviated from, except for varying periods of apprenticeship. The education of J. Collin Warren therefore shows how unusual a man he must have been. He was able to complete his collegiate course and most of the first year's curriculum at the Medical School during his college years, and he volunteered as a civilian medical cadet in the Union army soon after. The inactivity of the Service during his first year allowed him to complete another year's study at Jefferson Medical College. After a short period of active service, he completed the Harvard Medical School course and an internship at the Massachusetts General Hospital. Then he spent a three-year period of study abroad at the leading centers of Europe—a most remarkable educational occurrence for the time. Small wonder then that when he returned to Boston to practice surgery it was not the pre-Listerian surgery involving principally the extremities. Here was a new species of doctor, who had studied with Cohnheim in pathology, who had personally visited the laboratories of physiology (Bernard), anatomy (Ranvier), and so forth, and who saw the new fields that surgery was to conquer. The history of that conquest, involving abdominal and then thoracic surgery, along with the outstanding role that Warren was to play in the financing and building of the Harvard Medical School as it is today, is the story that is related in this book. This reviewer does not know a more delightful account of this golden age in surgery in America. Those familiar with the great men at Harvard during Warren's long years of service will meet familiar names on every page of this autobiography and the geographical development of Boston during that time is also of great interest to those in the area. Dr. Churchill is to be commended for what must have been a tremendous task in editing a manuscript such as this. It is not repetitious, and the flatness of its impersonal tone is much relieved by Churchill's lively comments. Altogether it is a welcome addition to the surgeon's library and an indispensable work in the history of surgery in America.

Jonathan Cohen, M.D.

Reconstructive and Reparative Surgery. Ed. 2. Hans May, M.D. Philadelphia, F. A. Davis Company, 1958. $30.00.

Plastic and reconstructive surgery, embracing as it does segments of all the surgical specialties, presents formidable problems in condensation of material into a one-volume text. Dr. May has courageously and quite successfully buttressed his own large personal experience in Munich and later in Philadelphia with an extensive and discriminating review of American and foreign literature to produce a book which should be of value not only to the plastic surgeon but also to the general surgeon or specialist who is aware of the importance of plastic surgical principles as applied to his own field.

A substantial section covering general reconstructive precepts is followed by a topographical presentation of the technical aspects of reconstructive surgery, with the main emphasis on treatment of congenital and acquired deformities of the face and of injuries of the hand. Throughout the body of the text frequent reference is made to the final section which is comprised of illustrated thumbnail case reports culled from the author's practice.

Those acquainted with the First Edition (1947) will find an expanded and very comprehensive bibliography, a significant addition to the section on hand surgery, and the inclusion of many new techniques as well as the deletion of some less promising procedures appearing in the older edition.

Dr. May's writing is characterized by a clarity of style which allows a quick grasp of the technical material. The chapter on wound healing is a good example of the author's ability to refine a mass of information which is placed in proper perspective by the introduction of interesting historical background. The illustrations by Mr. and Mrs. McNett which contributed significantly to the value of the First Edition have been amplified; some are in color.

In essence a workable text covering the general principles of plastic and reconstructive surgery presents many of the generally accepted techniques which will be useful particularly to general, plastic, and orthopaedic surgeons. Such a book must perforce be incomplete, but in most instances fields in which skimming has occurred have at least been covered adequately in the bibliography.

A criticism of both editions is the author's penchant for including more than is really necessary or indicated. For example, the cursory treatment of such subjects as intrathoracic surgery of the esophagus and of the blood vessels of the extremities, the inclusion of a chapter on the major articulations which discusses only arthroplasty and joint transplantation, and the recounting of the author's technique for hip-nailing, might better be omitted in favor of the fuller development of the more conventional aspects of such a text.

Radford C. Tanzer, M.D.

HEMOPHILIC ARTHROPATHIES. Henry H. Jordan, M.D. Springfield, Illinois, Charles C. Thomas, 1958.

The author has had an unusual opportunity to study and treat the arthropathies seen in patients with hemophilia. His work has been sponsored by the National Hemophilia Foundation which has been instrumental in sending a number of patients to the Hemophilia Clinic at the Lenox Hill Hospital in New York.

From an experience with 110 cases of hemophilic arthropathy, the author has compiled this presentation. It is an excellent summary of his experiences with this difficult problem. The treatment used to correct deformities is well outlined and illustrated and the entire plan of rehabilitation is well covered. The work is adequately illustrated and proper stress is given to the importance of accurate and careful application of casts and fitting of braces.

He has added twenty-one selected case histories to demonstrate specific aspects of hemophilic management and orthopaedic rehabilitation. Statistical summaries of the results of his work are given and an extensive chart showing the entire study and the results of the treatment program are added.

None of us has had extensive experience with this difficult condition and we believe this work is a very important one and may be used as a guide to the proper management of such problems.

Ralph K. Ghormley, M.D.

FUNCTIONAL BRACING OF THE UPPER EXTREMITIES. Miles H. Anderson, Ed.D. Edited by Raymond E. Sollars. Springfield, Illinois, Charles C. Thomas, 1958. $9.50.

This is an excellent book for anyone interested in the planning and application of functional bracing for the upper extremity. It is not a book for those interested in exploring the philosophy and theory of arm-bracing nor does it include any of the training techniques employed to allow these braces to provide the ultimate functional potential of which they are capable.

It is essentially a manual providing the details of construction of hand splints and functional arm braces for those paralytic affections of the upper extremity in which such bracing is useful; it is designed for the orthotic and prosthetic member of the brace team. The book is an outstanding contribution in this phase of the arm brace problem.

E. R. Schottstaedt, M.D.

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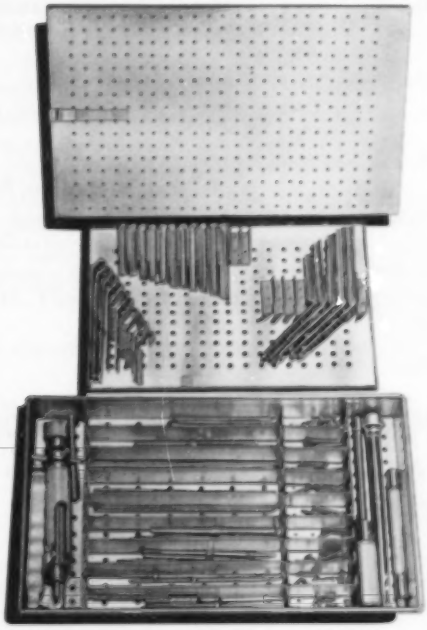

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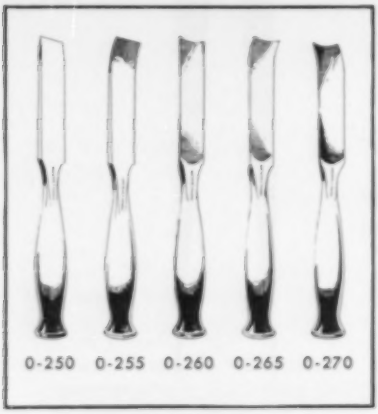

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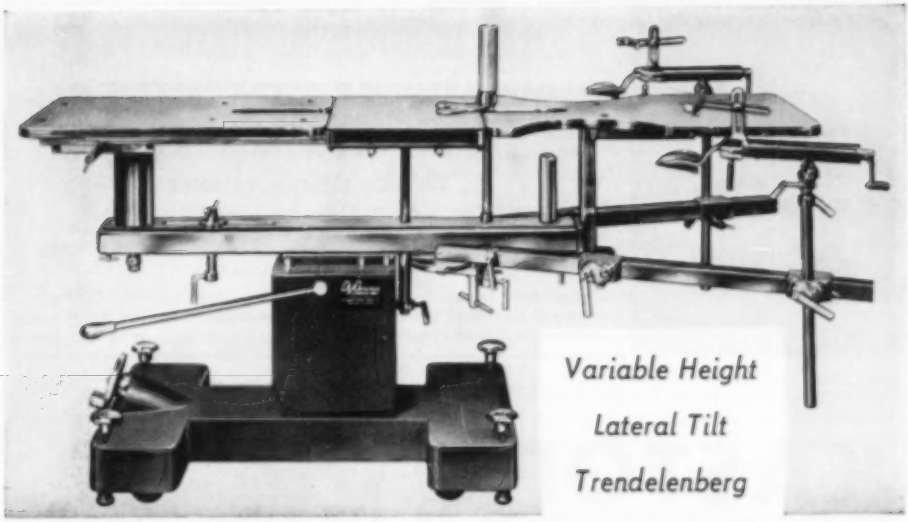

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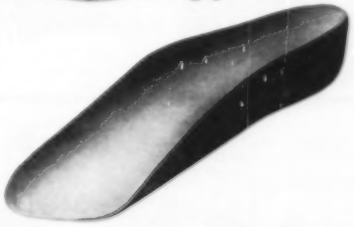

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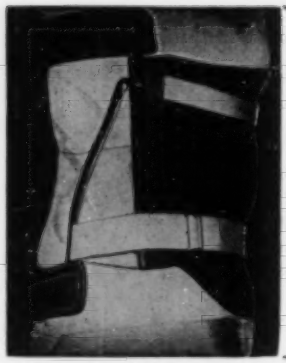

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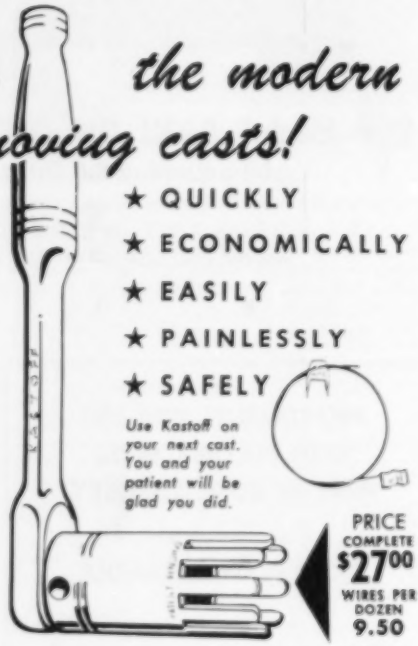

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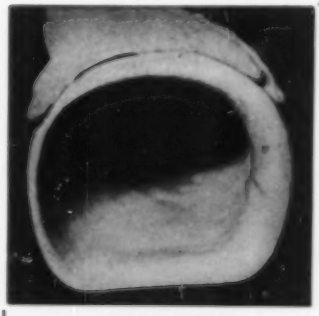

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